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Vol. 8-9
1933-34

Volume 8

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PERIODICAL
Journal du Conseil
Vol. 8-9
1933-34

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JOURNAL DU CONSEIL

VOL. VIII : NO. 1

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR

E. S. RUSSELL

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

AVRIL 1933

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CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER

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IMPRIMERIE A/S L. HIRICH

James Johnstone.

(1870—1932).

JAMES JOHNSTONE was born in 1870 at Beith, Ayrshire, and in the neighbouring village of Lochwinnoch he became an apprentice woodcarver, and later worked at the bench as a journeyman.

During these years there grew within him a desire for knowledge that remained unsatisfied in the last days of his illness. This was the driving force that urged him to long

hours of solitary study, and finally decided him at the age of twenty-five to leave the village he loved in order to prepare for a scientific career.

To this end he lived in London from 1895 to 1897 and attended classes in Biology and Physiology at the Royal College of Science, and in January 1898 he came to University College, Liverpool, as a fishery assistant under the late Sir William Herdman, who was at that time Professor of Zoology and honorary Scientific Director to the Lancashire Sea Fisheries Committee.

Johnstone published the results of his fishery investigations regularly in the annual reports of this Committee for more than thirty years, and his output was prodigious. The Report for 1904 is a notable one so far as he is concerned, for in it he indicated three main lines of investigation that were extended by him in the following years. The titles of the particular papers were: — »Bacteriological Investigations in Relation to Shellfish Pollution by Sewage Matter«, »Internal Parasites and Diseased Conditions of Fishes« and »Experiments in Marking Plaice«.

The existence of large mussel and cockle beds on the low-lying coasts of Lancashire and Cheshire and their exposure to sewage pollution in these thickly populated areas, presented a fishery problem of vital importance, and Johnstone was attracted to it in the interests not only of public health, but of the shellfish industry.

Realising the importance of certain laboratory experiments carried out by Dr. Klein which demonstrated that shellfish inoculated with *B. typhosus* tended to rid themselves of the bacteria when kept in sterile sea-water, Johnstone conceived the idea of transplanting mussels from the original beds to neighbouring shore areas that were free from pollution. Although this plan was far removed from the present elaborate and successful operations in mussel-cleansing carried out by the Ministry of Agriculture and Fisheries, credit must be given to him for pioneer work based upon the self-cleansing habits of shellfish.

Johnstone gathered together, over a number of years, an extensive collection of parasitised and diseased fishes, and these are described in the various Reports on the Lancashire Sea Fisheries Laboratory. His primary interest was in the theoretical considerations arising from the study of such pathological growths, but he also set himself the practical task of discriminating between edible fish that should not be

condemned unnecessarily and those that might be dangerous to health if sold for human food. The latter aspect of the subject finds an application in the classes for Sanitary Inspectors that are still carried on in the Department of Oceanography at Liverpool.

The work undertaken by Johnstone between 1904 and 1911 in connection with sea temperatures, the measurement and marking of plaice, and with the trawling observations carried out on the various fishing grounds by officers of the Committee, was given further impetus in 1912—13 when a substantial sum was granted from the Development Fund to assist fisheries research in the Lancashire Area. Much of this activity ceased in 1914, but by that time a definite picture had been presented of the annual migrations of plaice in the Irish Sea.

Such investigations called for exceptional diligence and analytical powers, and they were the fullest and most important constribution that Johnstone made to fishery science.

Faced with the problem of dealing with masses of figures he studied the statistical methods that are associated with the name of Karl Pearson. These were adapted by Johnstone to the particular problems, and he devised certain simple methods of graphing data that have undoubted interest for Biologists who may be engaged on similar lines of inquiry.

The ability to concentrate upon a subject in this way, and then to use it for a particular need was one of his outstanding qualities. During the earlier strenuous years at Liverpool he had attended University Courses in Chemistry, but this study was not complete for him until he had applied knowledge thus gained to certain problems of a biochemical nature.

Believing that the immediate future of biological science lay in the field of biochemistry he retained, nevertheless, an interest in morphology and never thought it old fashioned. In 1899 he had written a memoir on the structure of the common cockle *(Cardium edule)*, and as late as 1926 he collaborated in a paper on the general morphology of the parasitic Cirripede *Anelasma squalicola*.

Johnstone had a natural gift for writing and he derived great pleasure from this talent. His first book, »British Fisheries«, was published in 1905, and soon there followed »Conditions of life in the Sea« which may still be

regarded as a classic. His wide scientific and philosophical interests are reflected in »The Philisophy of Biology« (1914), »The Mechanism of Life« (1921), and »The Essentials of Biology« (1932).

With the assistance of his colleagues Chadwick and Scott he produced in 1924 »The Marine Plankton«, which embodied results of plankton investigations carried out in the Irish Sea by the late Sir William Herdman during the years 1907—14.

Two other books, »An Introduction to Oceanography«, first published in 1923 and now in its second edition, and »A Study of the Oceans« (1926), were based upon lectures given in the University of Liverpool.

In order to appreciate fully his constributions to fishery research it is necessary to remember that he was twenty-eight years of age before an opportunity came to carry out any investigations, and that during the greater part of his working life as a scientist there were certain routine duties to be carried out in the subordinate position he occupied as fishery assistant to a local Sea Fisheries Committee.

When in 1920 Johnstone was appointed Professor of Oceanography, he became at the same time Honorary Director of the Port Erin Biological Station, Honorary Director of scientific work to the Lancashire and Western Sea Fisheries Committee, Editor of the Annual Report of this Committee, and of the series of L. M. B. C. Memoirs that were issued from his Department on Typical British Marine Plants and Animals.

If the lean years made him, at times, somewhat impatient with authority, they also engendered in his kindly nature an anxious regard for the well-being of his own subordinates. Those of us who were under James Johnstone will always remember with tenderness the years in which it was a joy to serve him.

R. J. Daniel.

Some Modern Statistical Methods: their Application to the Solution of Herring Race Problems.

By

H. J. Buchanan-Wollaston,
Fisheries Laboratory, Lowestoft.

With a Foreword by

R. A. Fisher.

THE aim of statistical methods is to make available the whole of the information supplied by a body of data, in its logical bearing upon whatever theories are under discussion. In subjects to which such methods have been long developed, and for which highly adequate methods have been elaborated, the majority of readers will already understand what processes must have been applied to the observational material to elicit its meaning, and the results of elaborate calculations may be presented compactly in an intelligible form made familiar by convention. Attention may thus be concentrated on the results rather than on the methods, and the computer has no other anxiety than to carry out his part of the work with the high standard of competence already established. In subjects, on the other hand, in which new types of observational data come up for discussion, or in which information of new kinds is being sought, neither the research worker, nor his readers, enjoy the same advantages. Very much labour must be expended in discovering the limitations, both qualitative and quantitative, of the available material, in discovering to what questions it is not capable of giving an answer, labour which, while necessarily fruitless of positive results, may be necessary to clear the air of illfounded views, and in any case supplies the only possible foundation for designing the nature and extent of future observational programmes. Again when positive results are indicated, supplementary mathematical researches will often be found necessary to develop new tests of significance, appropriate for excluding sampling errors of unfamiliar types. All this makes such work not only difficult to do, but difficult to assimilate when done.

In the herring vertebra problem Mr. Wollaston has introduced a fundamental simplification by showing that, with samples of the sizes available, all apparent differences, in the form of the frequency distribution observed, are to be ascribed solely to differences in the mean vertebra number. The body of samples examined shows no signs of departure from a collection of grouped normal samples. What is even more remarkable, it appears that the variance, or measure of variability, within these samples, does not differ significantly from sample to sample. The whole intricate problem of treating these distributions is thus reduced to that of finding a satisfactory method of estimating the mean for such heavily grouped material, and this Mr. Wollaston has done in the first half of the paper .

The second half is devoted to a discussion of the observed variation in the mean vertebra number, according to the stage of maturity, and the geographical position of the sample. Again the greater part of the work necessarily consists in exploring the limitations of the data, or in elaborating statistical methods competent to overcome these limitations. There can be no doubt of the statistical reality (significance) of the differences in mean value observed, and it appears that they can be analysed into simply additive parts ascribable respectively to stage of maturity, and to region of origin. As Mr. Wollaston insists, such an analysis should not be treated as final, but rather as affording a rational basis on which to base more decisive observations.

R. A. F.

Herring Race Problems.

A Constructive Criticism of Statistical Methods at present in use.

Preface. There are two fundamentally different ways of approaching observational scientific data. The first is to lay out the data as graphically as possible and see what they suggest; the second, to formulate, without examining the data in detail, hypotheses which the data may be expected to prove or disprove, and then to test the agreement of the data with the hypotheses. The first result remains but a suggestion, and the actuality of the suggested phenomena cannot be stated in terms of probability. The second allows definite statement of probability that the hypotheses are true or not true. The great majority of fishery workers, including Dr. Schnakenbeck in his work criticized in this paper, have adopted the first way. His conclusions may be right, but his method of approach, which I will call the *a posteriori* method, includes no test whatever as to the probability of his being right.

Let us suppose that I am being dealt a hand at the game of Poker, and the chances of being dealt four aces and the Joker are discussed. The *a priori* chance of drawing this hand is undoubtedly very small, but it is exactly equal to that of drawing any other previously defined hand, namely $^{5}/_{53}\cdot^{4}/_{52}\cdot^{3}/_{51}\cdot^{2}/_{50}\cdot^{1}/_{49}$. Taking the suggestions offered by data, arranged according to their own values, as certainly indicating real phenomena, is analogous to considering the dealing of four aces and the Joker an extraordinary occurrence, overlooking the fact that it only seems extraordinary because "5 aces" is often at the back of a player's mind and therefore it has always the aspect of a defined hand, with the minute chance given above of turning up.

Sound statistical tests of probability can *only* be applied to data treated in the second way. It is even better to formulate hypotheses to be tested by the data before these are collected than to do so before they are worked up. The research can then be given the exactness of pure experimental science, giving equally definite positive or negative results.

The space distribution of Dr. Schnakenbeck's samples, as specified by "shape" of the frequency curve of vertebrae, is extremely *suggestive* but proves nothing. The shape is merely a function of the position of the mean. If now an entirely homogeneous set of frequency distributions homogeneously distributed in space were to be divided into sets characterized by low, medium and high means, a *suggestive* distribution in space would occur very often by pure chance. It is only when spatial distribution is defined beforehand that the agreement of the data with it can be considered significant.

In the following paper I have approached the matter by way of *a priori* hypothesis, and have detailed sound statistical tests of the probability of agreement between these and the phenomena indicated by the data.

A useful way of combining *a posteriori* suggestions with *a priori* hypothesis is to use the suggestions given by one set of observations as the hypotheses of a second. This is the test of consistency, but it cannot be applied in the case of the data on the present problem to which I have had access.

THE main object of this paper is to introduce into fishery research some of the most important methods developed by R. A. Fisher of Rothamsted Laboratory. These are offered as alternative and far preferable to empirical methods which take no account of the variability which occurs between samples drawn from a larger population. For the purpose in question I have used the data collected by Dr. Schnakenbeck from the North Sea,[1]) and I propose to show that Dr. Fisher's methods are perfectly adequate to deal with such data and to extract all the information from them which they are capable of giving. As I have not had access to subsidiary data, collected by other workers and used by Dr. Schnakenbeck in his report (1), it cannot be said definitely whether these would have modified my conclusions and brought them more nearly into line with Schnakenbeck's. It is hoped that all available data bearing on the herring race question will eventually be combined in a complete statistical analysis on the lines laid down here. This must be considered merely as an introduction to such analysis.

It would have been impossible for me to have carried out this analysis had I not had the great privilege of working under the personal supervision of Dr. Fisher at Rothamsted while engaged upon it. I must here express my gratitude to him for his help and his generosity in allowing me to publish results in which an extension of one of his methods is used for the first time. The basic mathematical theory underlying this analysis is entirely Dr. Fisher's, though the necessary computations were mainly carried out by myself. I must also thank Mr. Yates and Mr. Hopkins of Rothamsted for their very kind help in many cases in which I was held up by lack of mathematical training. Without this help it would have been impossible for me to complete the work. I must also express my gratitude to Prof. Ehrenbaum and Dr. Schnakenbeck himself for so kindly allowing me access to Dr. Schnakenbeck's original data, though they were fully aware that my object was criticism.

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[1]) My Table 1 gives the vertebral distribution, stage of ripeness of, and number in these samples, and also Schnakenbeck's Table No., by which reference may be made to Schnakenbeck's chart, Abb. 7, and his Table on p. 460.

Though the mathematical theory on which the present paper is founded is somewhat advanced, the methods introduced herein are very simple in application. The first part deals almost exclusively with Fisher's methods for finding the best-fitting Curve of Error to fit to highly grouped data. Readers who have not to deal with such data may prefer to omit this part. The second part (from page 23 on) deals with Fisher's method of the Analysis of Variance, which is of almost universal application in testing the significance of variations in any phenomenon under different conditions. There is no other method so ideally fitted for this kind of test. This second part will be therefore found worth reading by anyone who is engaged in fishery research and who is not familiar with Fisher's work. Every step in the application of the method to the present problem is shown in detail, and described as far as possible in non-mathematical language.

It is necessary first to make some criticisms of such empirical methods as are used by Schnakenbeck, before offering alternatives to them. Schnakenbeck, in attempting to distinguish herring races by the vertebral counts, avoids the use of ordinary statistics such as the mean, standard error and standard error of the mean. He prefers to use the "shape"[1]) of the frequency polygon of the vertebral numbers in a sample as a criterion of what he terms the "mode of variability" of the sample. It is difficult to understand what is meant by the "mode of variability". The "shape" of the curve is obviously a function of (1) the position of the mean in the interval of grouping, in this case the integral number unity, (2) the spread of the curve, (3) the skewness of the curve, (4) other departures from normality, such as kurtosis. The variability in "shape" in the case of Schnakenbeck's figures is, however, almost if not completely accounted for by variability in the position of the mean in the grouping interval; it will be shown that departures from normality are only such as would be expected from random sampling effects. Fig. 1 shows a set of normal frequency polygons, all having σ equal to .6 and only differing in the position of the mean in the interval, each successive mean differing by $^1/_{12}$ of the interval from the preceding. On examining Schnakenbeck's figures, it is fairly obvious without further mathematical research that every "shape" of polygon given by him is reproduced in one of the set of twelve within the error due to random sampling. We may, however, be asked whether it is justifiable to assume that Schnakenbeck's data may be regarded as samples from a normal population, a fair question, since integral counts are discontinuous, and limited in both directions, while the Curve of Error is continuous and unlimited in both directions. Now it is usual and, I think, perfectly justifiable to assume that there is a physiological variable underlying such phenomena as

[1]) The random sampling distribution of "shape" could possibly be found empirically. Unless this is done, no criterion exists for judgment whether one "shape" is significantly different from another.

vertebration, of which the force has continuous variation, and which may conceivably vary well beyond the range at which it can express itself discontinuously as number of vertebrae. This is all that is necessary to justify the trial of the fit of the Curve of Error to data, since there are no data in practice of which the range of variability is actually infinite in both directions. Discontinuous data such as vertebral counts may be regarded as having been grouped by

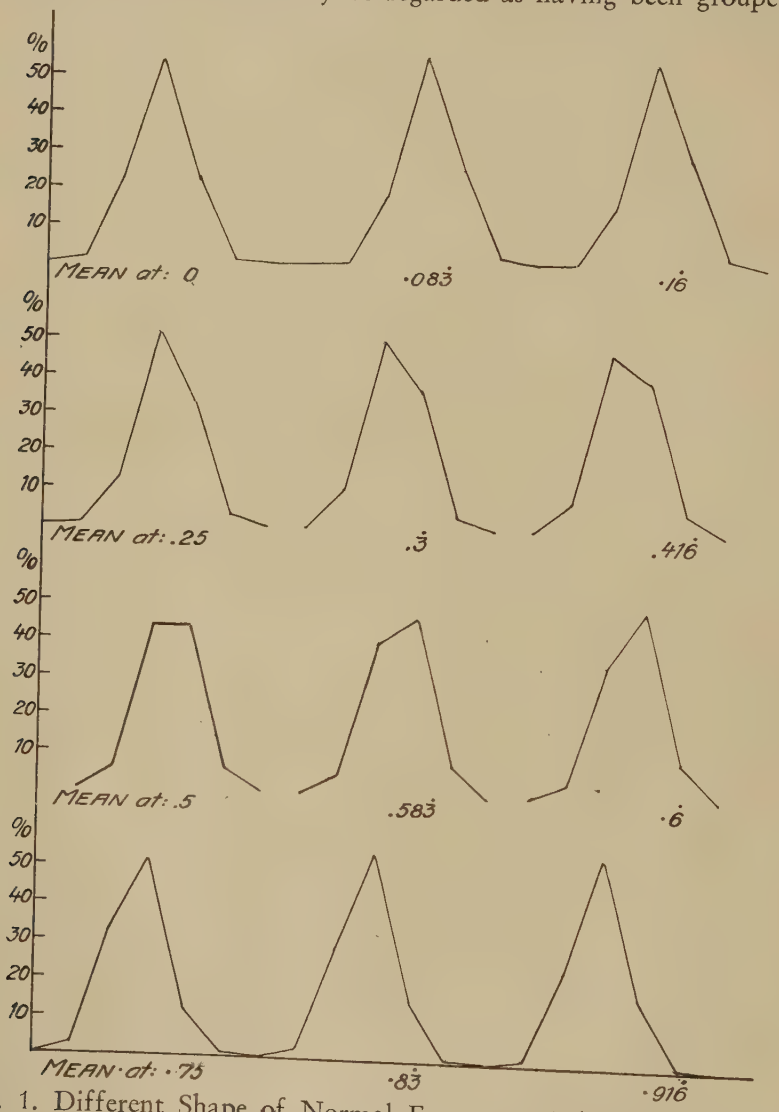

Fig. 1. Different Shape of Normal Frequency Polygon according to Position of Mean in Grouping Interval. Standard Deviation (σ) = .6̇.

nature and must be treated exactly as observational data which are grouped for convenience.

It has been shown (Fisher (2)) that where the group interval of a sample is less than a quarter of the standard deviation, the second moment about the mean, corrected by Sheppard's correction for grouping, is a *consistent* and an *efficient* estimate[1]) of the *variance*, or square of the standard deviation of the population from which the sample is drawn, in cases in which the sample may be assumed reasonably to have been drawn from a hypothetical infinite population conforming to the Normal Law of Error. The first moment, i. e. the mean as usually calculated, is also in this case a consistent and efficient estimate of the mean of the hypothetical population. Fisher shows that the moments of grouped samples are periodic in θ, where $\frac{\theta}{2\pi}$ is the fraction of the group interval, in angular measure, corresponding to the position of the mean. Thus, if the mean lies exactly at a definite number of vertebrae, $\theta = 0$, if half-way along an interval, $\theta = \pi$ and so on. Fisher (2) equated the general kth moment to the ordinary Fourier Series

$$\mu_k = A_0 + A_1 \sin\theta + A_2 \sin 2\theta + \ldots\ldots + B_1 \cos\theta + B_2 \cos 2\theta + \ldots\ldots$$

and developed general expressions for the first and second moments of a grouped normal population. The periodic terms are quite insignificant if the group interval is small compared to the standard deviation. The absolute term A_0 may be expanded as a series and Sheppard's correction for the second moment is merely the second term of this series.

In very highly grouped data such as herring vertebral counts, the first harmonic term is by no means inappreciable, nor is Sheppard's correction at all a near estimate of the necessary correction due to the absolute term A_0, since the further terms of the series mentioned are not small. The second harmonic terms $A_2 \sin 2\theta$ and $B_2 \cos 2\theta$ are insignificant in the order of grouping represented by herring vertebral counts.

Since the first and second moments do not give the centres and variances of the best-fitting Curves of Error for our data, we must have recourse to a general method which Fisher has invented for finding for any random sample the parameters of the best-fitting frequency-curve of any given mathematical form, that is to say the curve of the chosen form which would yield the random sample in question more frequently than any curve of the said form having different parameters. This method is called by Fisher the Method of Maximum Likelihood (See Fisher (2) and (3)). It consists in making the combined chances of the occurrence of our sample values, viewed as having arisen from an infinite population of the chosen

[1]) The definition of this term and other statistical terms will be found in Appendix 1 of this paper.

form, a maximum for variations in the parameters of that population. The product of all the separate chances, or, what comes to the same thing, the sum of their logarithms, has to be maximized in the usual way, by equating to zero the differential coefficient of this sum with respect to each parameter, and solving the equations.

In the present instance, the chance of a sample value falling in the interval $x_{s+1} - x_s$ is

$$p_s = \frac{1}{\sigma\sqrt{2\pi}} \int_{x_s}^{x_{s+1}} e^{-\frac{(x-m)^2}{2\sigma^2}} \cdot dx$$

or, writing

$$\xi = \frac{x-m}{\sigma}, \quad p_s = \frac{1}{\sqrt{2\pi}} \int_{\xi_s}^{\xi_{s+1}} e^{-\frac{1}{2}\xi^2} \cdot d\xi$$

Thus we write

$$\frac{\partial(S \log p_s)}{\partial m} = \frac{\partial L}{\partial m} = -S\frac{n'_s}{p_s} \cdot \frac{1}{\sigma}(z_{s+1} - z_s) = S\frac{n'_s}{p_s\sigma}(z_s - z_{s+1}) = 0$$

where n'_s is the proportional frequency in the sample in the interval $\xi_{s+1} - \xi_s$ and

$$z_s = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-\frac{1}{2}\xi_s^2}$$

Similarly

$$\frac{\partial L}{\partial \sigma} = S\frac{n'_s}{p_s\sigma}(z_s\xi_s - z_{s+1}\xi_{s+1}) = 0$$

In practice the term $\frac{1}{\sigma}$ may conveniently be omitted, and we may write

$$P = S\frac{n'_s}{p_s}(z_s - z_{s+1}) = S\frac{n'_s}{p_s}(\delta z) = 0$$

$$Q = S\frac{n'_s}{p_s}(\delta\xi z) = 0$$

In practice, a first approximation to the optimum values of m and σ is made from the moments in the usual way, using Sheppard's correction for the variance[1]). Then the values of P and Q are calculated from the data and from the proportional areas etc. of the Curve of Error fitted by moments. It will be found as a rule that P and Q are by no means zero. We now need a correction to apply to m and σ to give a second approximation to the optium values $\hat{m}$ and $\hat{\sigma}$.

By a well-known method of continual approximation

$$\frac{\partial^2 L}{\partial m^2}\delta m + \frac{\partial^2 L}{\partial m \partial \sigma}\delta\sigma = -\frac{\partial L}{\partial m}$$

$$\frac{\partial^2 L}{\partial \sigma \partial m}\delta m + \frac{\partial^2 L}{\partial \sigma^2}\delta\sigma = -\frac{\partial L}{\partial \sigma}$$

[1]) The symbol S stands for summation over the whole sample, or, in cases of theoretical distributions, over the whole theoretical population.

These, on solution as a pair of simultaneous equations, yield the necessary corrections δm and $\delta\sigma$ to be applied to m and σ to give a second approximation to the optimum values.

Working in P and Q, the equations are

$$\frac{\partial P}{\partial m}\delta m + \frac{\partial P}{\partial \sigma}\delta\sigma = P$$

$$\frac{\partial Q}{\partial m}\delta m + \frac{\partial Q}{\partial \sigma}\delta\sigma = Q$$

Differentiating P and Q with respect to m and σ, we obtain

$$\frac{\partial P}{\partial m} = \frac{1}{\sigma} S\frac{n'_s}{p_s}\delta(\xi z) - \frac{1}{\sigma} S\frac{n'_s}{p_s}[\delta(z)]^2$$

$$\frac{\partial P}{\partial \sigma} = \frac{1}{\sigma} S\frac{n'_s}{p_s}\delta(z\xi^2) - \frac{1}{\sigma} S\frac{n'_s}{p_s}\delta(z)\,\delta(\xi z)$$

$$\frac{\partial Q}{\partial m} = \frac{1}{\sigma} S\frac{n'_s}{p_s}[\delta(\xi^2 z) - \delta(z)] - \frac{1}{\sigma} S\frac{n'_s}{p_s}\delta(\xi z)\,\delta(z)$$

$$\frac{\partial Q}{\partial \sigma} = \frac{1}{\sigma} S\frac{n'_s}{p_s}[\delta(\xi^3 z) - \delta(\xi z)] - \frac{1}{\sigma} S\frac{n'_s}{p_s}[\delta(\xi z)]^2$$

These expressions are somewhat complicated and need to be worked anew for each sample. Dr. Fisher has suggested that the *mean* values of $\frac{\partial P}{\partial m}$ etc. for different values of σ and for different positions of the mean in the grouping interval — different *phases* of the mean — would probably suffice for continued approximation. Mr. Yates kindly worked an example by the long method against my working by the method of the mean values and the corrections given by the short were very nearly as useful as those given by the long method. The method of the mean values was therefore adopted, with good results. The mean values are those which would be found for the whole hypothetical *grouped* population. No account is taken of random sampling errors but merely of the fact that the moments do not give the true mean and the true standard deviation of the whole infinite hypothetical population, *if highly grouped*, though it *exactly* fits the Curve of Error. The mean and s calculated from the moments are *inconsistent*[1]) estimates of the true values.

The mean value of $\frac{n'_s}{p_s} = 1$, n'_s being here the proportional frequency, and the mean values of the first terms in the expressions for $\frac{\partial P}{\partial m}$ etc. are equal to zero.

[1]) See Appendix (1).

We have therefore

$$\text{Mean } \frac{\partial P}{\partial m} = -\frac{1}{\sigma} S \frac{1}{p_s} [\delta(z)]^2$$

$$\text{,, } \frac{\partial P}{\partial \sigma} = \frac{\partial Q}{\partial m} = -\frac{1}{\sigma} S \frac{1}{p_s} [\delta(z)][\delta(\xi z)]$$

$$\text{,, } \frac{\partial Q}{\partial m} = -\frac{1}{\sigma} S \frac{1}{p_s} [\delta(\xi z)]^2$$

The necessary computations for working out these mean values were very lengthy. It was thought desirable to carry them to such a degree of accuracy as would show whether they fitted a simple harmonic in θ, the phase of the mean, or whether a second harmonic was appreciable. Pearson's Tables of the ordinates and areas of the Curve of Error do not carry the values to the required degree of accuracy and Burgess's Tables had to be used. These employ the modulus ($\sqrt{2}\sigma$) in place of σ. As it was necessary to use values corresponding to 5 times the modulus or more, and to values of the modulus not tabulated, much interpolation and sub-tabulation had to be undertaken, and many values of z calculated direct. Several serious errors in the latter part of Burgess's Tables were found and this caused much delay. A very useful check on tabulated values of z and of the areas of the Curve of Error is described in Appendix 4 of the present paper. This check also provides a rapid method of calculating successive, equally spaced values of z, which is useful in cases where extreme accuracy is not required.

Three values for the grouping interval, in terms of the modulus, were employed in my computations, namely 1.08, 1.20, and 1.32, each being combined with 12 different phases of the mean, which was at 0, .09, .18 moduli in the first set; at 0, .1, .2, etc. in the second; at 0, .11, .12, etc. in the third, thus corresponding to the 12 positions of the mean given in Fig. 1.

The computations were carried out in Burgess's expressions for the ordinates and areas.

Burgess's

$$z = \frac{2}{\sqrt{\pi}} e^{-\frac{1}{2}\left(\frac{x-m}{\sigma}\right)^2} \qquad p = \frac{2}{\sqrt{\pi}} \int_0^{\xi} e^{-\xi^2} \qquad \xi = \frac{x-m}{\sqrt{2}\sigma}$$

while in Pearson's Tables

$$z = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-m}{\sigma}\right)^2} \qquad p = \frac{1}{\sqrt{2\pi}} \int_0^{\xi} e^{-\frac{1}{2}\xi^2} \qquad \xi = \frac{x-m}{\sigma}$$

and the values computed were, using Burgess's expressions,

$$S\frac{1}{p_s}(\delta z)^2 \qquad S\frac{1}{p_s}[\delta(z)][\delta(\xi z)] \qquad \text{and } S\frac{1}{p_s}[\delta(\xi z)]^2$$

which are $-4\sigma\frac{\partial P}{\partial m}$, $-2\sqrt{2}\sigma\frac{\partial Q}{\partial m}$ or $-2\sqrt{2}\sigma\frac{\partial P}{\partial \sigma}$ and $-2\sigma\frac{\partial Q}{\partial \sigma}$

respectively. In the above expressions δz stands for $z_s - z_{s+1}$ and so on, while p_s stands for the area between the ordinates z_{s+1} and z_s.

Modulus $= \frac{1}{1.08}$

Phase of Mean			
0	3.349999	2.843231	0
.08$\dot{3}$ or .91$\dot{6}$	3.349994	2.844484	— or + .0010324
.1$\dot{6}$ or .8$\dot{3}$	3.349782	2.847908	— or + .0017882
.25 or .75	3.349566	2.852584	— or + .0020649
.$\dot{3}$ or .$\dot{6}$	3.349349	2.857261	— or + .0017882
.41$\dot{6}$ or .58$\dot{3}$	3.349191	2.860685	— or + .0010324
.5	3.349133	2.861938	0
Mean Value	3.349566	2.852584	0

Modulus $= \frac{1}{1.20}$

Phase of Mean			
0	3.229315	2.629294	0
.08$\dot{3}$ or .91$\dot{6}$	3.229005	2.634429	— or + .0048647
.1$\dot{6}$ or .8$\dot{3}$	3.228157	2.648458	— or + .0084259
.25 or .75	3.227000	2.667622	— or + .0097294
.$\dot{3}$ or .$\dot{6}$	3.225843	2.686785	— or + .0084259
.41$\dot{6}$ or .58$\dot{3}$	3.224996	2.700814	— or + .0048647
.5	3.224686	2.705949	0
Mean Value	3.227000	2.667622	0

Modulus $= \frac{1}{1.32}$

Phase of Mean			
0	3.110011	2.384211	0
.08$\dot{3}$ or .91$\dot{6}$	3.108934	2.398156	— or + .0150573
.1$\dot{6}$ or .8$\dot{3}$	3.105992	2.436256	— or + .0260810
.25 or .75	3.101972	2.488302	— or + .0301143
.$\dot{3}$ or .$\dot{6}$	3.097952	2.540350	— or + .0260810
.41$\dot{6}$ or .58$\dot{3}$	3.095009	2.578452	— or + .0150573
.5	3.093932	2.592399	0
Mean Value	3.101972	2.488302	0

It was found that the expressions tabulated fitted well a simple harmonic in the phase of the mean, the test of the fit being carried

out on the second differences. These agreed with the harmonic to the 6th or 7th decimal place, and disagreement beyond this place was probably due to slight inaccuracies in the interpolated values of the ordinates or areas of the Curve of Error for high values of the modulus.

It will be seen from the values of $\frac{\delta P}{\delta m}$ that the harmonic variation is hardly worth considering in practical approximation. The harmonic variation in $\frac{\delta Q}{\delta \sigma}$ is however quite considerable and rises rapidly as σ is decreased. The value of $\frac{\delta Q}{\delta m}$ is so small for all phases of the mean and values of σ that it is not worth considering for purposes of approximation.

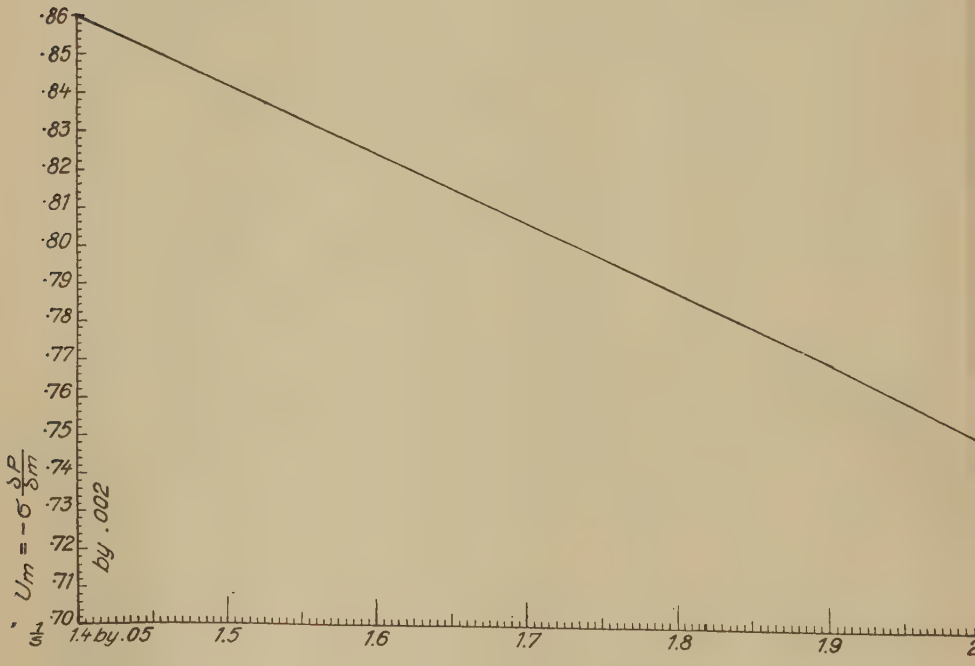

Fig. 2. Graph for finding Value of U_m corresponding to any given Value of $\frac{1}{s}$ between 1.4 and 2.0.

As the value of s, the estimate of σ computed from a sample, is not likely to be exactly equal to one of the three values for which the derivatives are tabulated, I have drawn graphs Fig. 2 and Fig. 3 for them, so that intermediate values of the derivatives may be read off at a glance. The use of these graphs is very simple, as will be

seen from the following example, which shows in complete detail the procedure of fitting one of Schnakenbeck's samples (No. 1) to the best-fitting Curve of Error. The abscissae of the graphs are $\frac{1}{s}$ and the ordinates $\sigma \frac{\partial P}{\partial m}$ and $\sigma \frac{\partial Q}{\partial \sigma}$, the values tabulated having been divided by 4 and 2 respectively.

The sample in question is as follows:—

Vertebrae	55	56	57	58	59
Number of Fish	0	5	9	1	0

Taking a working mean at 55 vertebrae, we have

Number in Sample $= n' = 15$
Total Excess above $55 = Sx = 26$
Mean Excess $= \bar{x} = 1.73 = m$
Mean $= 55 + 1.73 = 56.73$
$S(x^2) = 50$

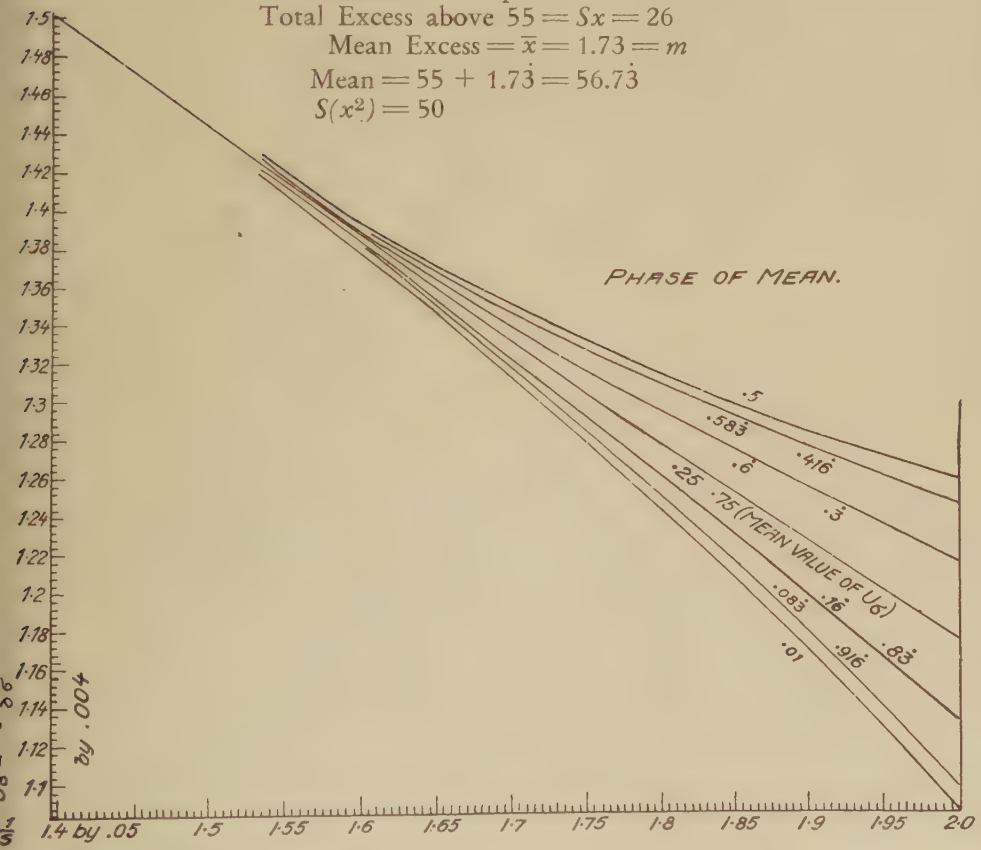

Fig. 3. Graph for finding Value of U_σ corresponding to any given Value of $\frac{1}{s}$ between 1.4 and 2.

$$S(x-\bar{x})^2 = S(x^2) - \bar{x}\,Sx = 4.93342$$

$$\text{Estimated Variance} = s^2 = \frac{S(x-\bar{x})^2}{n'-1} = .35239$$

$$s^2 - .083 = .26905 = \text{new Estimated Variance}$$

$$s = \sqrt{.26905} = .51869$$

Vertebrae ..	55	.5	56	.5	57	.5	58	.5	59
$(x-\bar{x})$	— 1.23333		— .23333		+ .76666		+ 1.76666		
$\frac{x-\bar{x}}{s} = \xi$	— 2.37777		— .44984		+ 1.47807		+ 3.40600		
z (from Pearson's Tables)	.023617		.360581		.133818		.001207		
p = area between Mean and ξ (from Pearson's Tables)	.491291		.173587		.430304		.499670		
$z\,\xi$	— .056156		— .162204		+ .197792		+ .004111		
$\delta(z) = z_s - z_{s+1}$	— .336964		+ .226763		+ .132611				
$\delta(p) = p_s$	— .317704		— .603891		— .069366				
$\delta(\xi z)$	+ .106048		— .359996		+ .193681				
$\frac{\delta z}{\delta p}$	+ 1.060623		— .375503		— 1.911757				
$\frac{\delta z\,\xi}{\delta p}$	— .333795		+ .596128		— 2.792160				
n'_s	5		9		1				

$$S\frac{n'_s}{p_s}\delta(z) = .011831 = P \qquad S\frac{n'_s}{p_s}\delta(\xi z) = .904017 = Q$$

$$\frac{1}{s} = 1.92793 \qquad \text{Phase of Mean} = .23$$

Taking 1.92793 as the abscissa of the values required from the graphs, which give $-\sigma\frac{\delta P}{\delta m}$ and $-\sigma\frac{\delta Q}{\delta\sigma}$ respectively, calling these values Um and $U\sigma$ respectively, and solving the equations

$$\frac{\delta P}{\delta m}\delta m = P \quad \text{or} \quad \delta m = \frac{-sP}{n'U_m}\ ^{1})$$

$$\frac{\delta Q}{\delta\sigma}\delta s = Q \quad \text{or} \quad \delta s = \frac{-sQ}{n'U_\sigma}\ ^{1})$$

we find approximately

$$\delta m = -.0005351$$
$$\delta s = -.0256232$$

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[1]) n' occurs in these expressions because n'_s has been taken as the actual and not the proportional frequency in each class.

The new values of m and s are therefore

$$m = 56.73333 - .0005351 = 56.73279$$
$$s = .51869 - .0256232 = .4930668$$
$$\frac{1}{s} = 2.0281228$$

Phase of Mean = .23, as before.

Second working for P and Q.

$\bar{x} = 56.73279, \quad s = .4930668 \quad \frac{1}{s} = 2.0281228$

$(x - \bar{x})$	— 1.23279	— .23279	+ .76721	+ 1.76721
ξ	— 2.500250	— .472127	+ 1.555996	+ 3.584119
z	.017517	.356865	.118899	.000648
p	.493795	.181581	.440143	.499831
$z\xi$ ...	— .043797	— .168486	+ .185006	+ .002323
$\delta(z)$	— .339348	+ .237966	+ .118251	
$\delta(p)$	— .312214	— .621724	— .059688	
$\delta(z\xi)$	+ .124689	— .353492	+ .182683	
$\frac{\delta(z)}{\delta(p)}$	+ 1.086908	— .382752	— 1.981152	
$\frac{\delta(z\xi)}{\delta(p)}$	— .399370	+ .568568	— 3.060632	

$P = .008620 \qquad \delta m = - .0003803$

$Q = .059630 \qquad \delta s = - .0016811$

New values for m and s

$$m = \underline{56.73241} \qquad \frac{1}{s} = 2.0350600$$
$$s = \underline{.491386}$$

A further working for P and Q gives

$P = .000642$

$Q = .002291$

The graphs with abscissa = 2.035 give

$U_m = .745, \quad U_\sigma = 1.166$

Thus $\delta m = - .00003$

$\delta s = - .00006$

The underlined values are therefore correct to four places of decimals.

This process of continued approximation to the best estimates of m and σ seems somewhat tedious. After carrying out the working for P and Q several times, however, the process becomes very rapid. It is not necessary to use differences beyond the first — ordinary proportional interpolation — when interpolating in Pearson's Tables for z and p.

It should be emphasized that *efficient* estimates of the parameters *must* be used if the χ^2 test of fit is to be applied, otherwise the χ^2 distribution is not realized and the test is quite unsound. It should be mentioned also that the χ^2 test cannot be applied when the number of classes is three or under; since the total, mean, and σ are estimated

from the sample, and since there are only 3 frequency classes, there are no degrees of freedom left as a basis for the test. The fit is, of course, almost absolute, p_s and n'_s agree to the nearest whole number, and the slight misfit is due merely to the use of an infinitely extended distribution to fit a limited distribution. It may be assumed, however, that a grouped Curve of Error, having parameters estimated by the Method of Maximum Likelihood, fits all samples having three frequency classes only, so long as the central frequency is the highest. The only doubt occurs in samples having 4, 5 or more frequency classes and we will therefore test a few of Schnakenbeck's samples of this class, choosing those which, when the end classes are combined to give a frequency of at least 4, will leave one or more **degrees of freedom**[1]) for the χ^2 test.

I have tested Samples No. 2 (IV and V), No. 8 (juv.), No. 12 (V), No. 16 (V), and No. 19 (V) in this way, first adjusting the mean and standard error to agree with the maximum likelihood values to the third decimal place. The results are as follows:—

Sample No. 2 (IV and V), Mean 56.4509, Standard Error .7002

Observed	4	29	25	4
Calculated	5.482	27.215	25.062	4.2403
χ^2	.4006	.1170	.0002	1.3617

Total $\chi^2 = 1.8813$

Entering Fisher's Table of χ^2 (Fisher (4), Table III) we find that, for $n = 1$, $P > .1 < .2$, thus between one in five and one in ten samples from a normal population would give a greater misfit than this sample.

Sample No. 8 (juv.), Mean 56.579, Standard Error .716

Observed	6	19	32	5
Calculated	4.096	24.191	27.560	6.153
χ^2	.885	.956	.715	.216

Total $\chi^2 = 2.772$ $P = .1$ approximately.

Sample No. 12 (V), Mean = 56.507, Standard Error = .622

Observed	4	37	35	5
Calculated	4.27804	35.87491	36.37824	4.46881
χ^2	.0181	.0353	.0523	.0631

Total $\chi^2 = .1688$, $P > .6 < .7$

Sample No. 16 (V), Mean = 56.627, Standard Error = .637

Observed	10	102	144	21
Calculated	10.663	105.98699	136.72551	23.62425
χ^2	.0413	.14998	.38704	.29151

Total $\chi^2 = .86983$, $P > .3 < .5$

Sample No. 19 (V), Mean = 56.559, Standard Error = .676

Observed	6	58	76	8
Calculated	8.65618	60.19768	67.03952	12.10661
χ^2	.81506	.08023	1.19765	1.39298

Total $\chi^2 = 3.47652$, $P > .05 < .1$

[1]) See Appendix 1.

Thus, taking the generally used level of significance of .05, none of these five samples show a significant misfit from the normal distribution[1]). In the whole set of 48 samples one would expect two or so to give a χ^2 having P less than .05, according to normal theory. It would seem likely, for instance, that Sample 27 (IV and V) would show a significant misfit, and possibly Samples 30 (juv.) and 33 (V). It is not practicable to test any of these owing to there being too few observations in the end cells, but, even if such suspected misfit is actual, it is to be expected on the theory of pure chance. It is completely reasonable then to assume that all Schnakenbeck's samples are from a normal distribution, and that such abnormalities as occur are entirely due to random sampling error. Skewness, where it occurs, is definitely non-significant, as is also the fact that in certain cases one tail of the curve is much longer than the other. All *significant* variations in shape are due to difference in means. As all the samples may reasonably be assumed to be samples of a grouped normal population, *a fortiori* will their variances, standard errors and means agree in their distribution with normal expectation, that is to say, with the expected distributions of estimates of these parameters deduced from samples, since for this to hold good sufficiently for practical statistical purposes, it is not necessary for the sample distribution to be strictly normal.

We have then an ideal set of conditions for the application of Fisher's **Analysis of Variance**[2]) which is a powerful weapon for distinguishing between real differences between samples and those which are probably due to variation "within samples".

This is not the place to give a full description of the Analysis of Variance, but I propose to discuss shortly in non-mathematical language the assumptions on which it is founded, since I did not myself find Fisher's own description (Fisher (4)) very easy to follow, nor do I consider that the logical bases of the method were sufficiently emphasized in the work cited.

Supposing then for the moment that every single one of our vertebral counts is a sample from a strictly normal population of vertebral counts, we can take *at random* from the whole set of counts any given number of counts n_1', and calculate for the set the mean number $\bar{x}_1$, and the variance, $\frac{S(x_1 - \bar{x}_1)^2}{n_1}$ where $n_1 = n_1' - 1$. This variance, which we will call s_1^2, is an *estimate* of the variance σ^2 of the whole population, founded on the number of degrees of freedom n_1. The term degrees of freedom means the number of ways in which the frequencies of the counts may be varied at will, provided that given fixed relations between the data are adhered to. In calculating

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[1]) See Appendix 3 on the χ^2 distribution.

[2]) The term Analysis of Variance is somewhat misleading. It is the total Sum of Squares which is analyzed. If, however, each estimate of variance is considered as weighted by its degrees of freedom, the term Analysis of Variance is quite correct, as will be seen later.

s_1^2 we have used $\bar{x}_1$ as an estimate of the true mean, $\bar{x}_1$ being calculated from the data themselves. As $\bar{x}_1$, or the sum of all the n_1' x_1's, is fixed, only $n_1' - 1$ of them may be varied at will, the last being fixed by the sum of the $n_1' - 1$, whatever its value.

We can take any other random sample of n'_r counts and obtain another estimate s_r^2 of the variance σ^2, based on n_r degrees of freedom. We can also obtain s_t^2 from our total set of N' counts and this is an estimate of σ^2 based on $N' - 1$ degrees of freedom. All these values of s^2 may be shown to be *efficient* estimates of σ^2, provided that our total set of counts is normally distributed, and our choice of sub-samples is strictly random and not influenced in any way by the counts themselves. Besides these groups of counts chosen singly, we may separate all the counts into any number $n's$ of sets, containing say n'_1, n'_2 . . . n'_r counts, and find their means $\bar{x}_1$, $\bar{x}_2$ . . . $\bar{x}_r$. Then, if $\bar{\bar{x}}$ be the grand mean of all the counts,

$$\frac{n'_1(\bar{x}_1 - \bar{\bar{x}})^2 + n'_2(\bar{x}_2 - \bar{\bar{x}})^2 + \ldots + n'_r(\bar{x}_r - \bar{\bar{x}})^2}{n'_s - 1}$$

or

$$\frac{Sn_p(\bar{x}_p - \bar{\bar{x}})^2}{n'_s - 1}$$

is an estimate of σ^2, based on n_s degrees of freedom. We have here assumed that the individual counts in each set are concentrated at their means, and used the weighted means instead of the individual counts. This is perfectly allowable if the sets are random samples from a normal population.

Thus we may *analyse* the total sum of squares in many ways on the assumption of normal distribution, the various sums of squares being divided (within errors of random sampling) proportionately to the degrees of freedom involved.

Fisher has shown that if

$$z = \log_e \sqrt{\frac{s^2_m}{s^2_n}} \text{ or } \tfrac{1}{2}(\log_e s^2_m - \log_e s^2_n)$$

where s^2_m and s^2_n are two estimates of σ^2 based on m and n degrees of freedom respectively, then z is distributed in a known manner. If the value of z, found from two estimates of σ^2, calculated from data, lies too far away from the centre of this distribution, it may be reasonably concluded that s^2_m and s^2_n are *not* estimates of the *same* variance σ^2, indicating that the samples from which they were calculated were not randomly chosen but show an effect of the method of choice. This is the fundamental principle of the Analysis of Variance, but some of its applications involve very complex parcelling of the data into groups, and groups within groups. In all these cases, the method is used to test suspected effects of particular ways of parcelling the data, causing differences between some groups or means etc., and others, allowance being made automatically for variance *within* groups, i. e. for differences between the parcels which could

arise by chance. The z-test offers a sound criterion for judgment as to whether the suspected effects are real or not, without personal opinions having the slightest influence on our judgment. The distribution of z is a function of n_m and n_n, the degrees of freedom involved in the two estimates of σ^2 to be compared. Fisher has tabulated (4) the 5 % points and 1 % points in the z-distribution for various values of n_m and n_n. If our value of z lies outside the 5 % points, the two variances s^2_m and s^2_n are considered significantly different; if z is outside the 1 % point, the difference is considered doubly significant, as a value of z beyond our value would only occur by chance, if s^2_m and s^2_n are not really different, 1 in 20 times in the former case and 1 in 100 times in the latter. The main advantage of using variance as a measure of variability lies in the additive property of the sums of squares, and of the degrees of freedom. Thus we may add together $S(x_m - \bar{x}_m)^2$ and $S(x_n - \bar{x}_n)^2$ and obtain an efficient estimate of σ^2 founded on $n_m + n_n$ degrees of freedom, or we may divide our whole sample of counts into n', sets, with n'_1, n'_2 .. n'_r counts in the different sets, as we did when considering weighted means and obtain

$$\frac{S(x_1 - \bar{x}_1)^2 + S(x_2 - \bar{x}_2)^2 + \ldots + S(x_r - \bar{x}_r)^2}{n_1 + n_2 + \ldots n_r}$$

or $\frac{SS(x_p - \bar{x}_p)^2}{N' - r}$ as an estimate of σ^2 based on $N' - r$ degrees of freedom. This last estimate is usually called the variance "within classes" while that based on weighted means is called the variance "between classes". It should be mentioned that, in adding the sums of squares about the group means and dividing by the total number of degrees of freedom involved, we are assuming that the variances *within* the different groups are not significantly different. If significant differences are suspected, the z-test should be applied, since the Analysis of Variance is not sound if such differences are found.[1])

The Analysis of Variance may be applied to test the significance of differences not only between samples grouped according to any outside factor such as time, and space, or experimental treatment or a combination of them, but also to sub-samples within samples, for instance to differential response of a crop to nitrogen according to whether potash is also applied or not. However the total variance is analysed, there always remains a variance "within classes", i. e. a variability among measurable experimental or natural quantities, although the circumstances governing them are made as uniform as possible, either by wise experimental arrangement or by wise choice of method of collection of natural data. This "residual" variance is used as experimental "error" with which to compare any variance which may be expected to show the effect of a particular partitioning of data.

[1]) The variance "within classes" is the weighted mean of all the sample variances, the weights being the numbers of counts in the samples, less one in each case.

Table 1. Details of Schnakenbeck's Samples analyzed in this Report.

Table No.	Ripeness	Number in Sample	Vertebral Number							Area Class	Ripeness Class	S (x) 56=0	S (x²) 56=0	$\bar{x}$ 56=0	s^2
			53	54	55	56	57	58	59						
1	I + II	15				5	9	1		A	U	11	13	.73	.35239
„	III	107			2	44	53	8		„	I	67	87	.62617	.42496
„	IV + V	94			3	50	35	6		„	R	44	62	.46809	.44519
2	III	61			2	17	37	5		„	I	45	59	.73771	.43004
„	IV + V	62		1	3	29	25	4		„	R	28	48	.45161	.57959
4	IV	49		1	1	17	25	5		B	R	32	50	.65306	.60629
„	V	58			1	29	26	2		„	R	29	35	.50000	.35965
6	I + II	16				4	11	1		„	U	13	15	.81250	.20583
„	III + IV	40		1	0	17	19	3		„	I	23	35	.57500	.60962
„	V	62			1	19	40	2		„	R	43	49	.69355	.31438
8	juv.	62			6	19	32	5		„	J	36	58	.58065	.60813
10	I + II	21				8	12	1		„	U	14	16	.6	.3
„	V	35			1	15	14	5		„	R	23	35	.65714	.58488
„	VII	44		1	1	21	20	1		„	R	19	29	.43182	.48361
12	V	81			4	37	35	5		„	R	41	59	.50617	.47809
14	V	93	1	0	2	33	51	6		C	R	58	86	.62366	.54159
16	V	277		2	8	102	144	21		„	R	174	244	.62816	.48804
19	V	148	1	1	4	58	76	8		B	R	83	125	.56081	.53370
20	V	93			3	35	49	6		C	R	58	76	.62366	.43290
24	I + II	31				6	20	4	1	A	U	31	45	1.00000	.46
„	III + IV	41				21	20			„	I	20	20	.48781	.25609
25	I + II	25				4	16	5		B	U	26	36	1.04000	.37333
„	III + IV	39			4	20	13	2		„	I	13	25	.3	.54386

„	IV + V	197	2	0	13	95	84	2	1	„	R	72	132	.36548	.53922
29	I + II	47			2	15	27	3		B	U	31	41	.65958	.44679
30	Juv.	91	2(52)[1]	2	7	38	37	5		„	J	36	72	.40449	.65271
32	V	109	1	0	9	56	40	2	1	„	R	35	75	.32110	.59039
33	III + IV	28			2	13	12	1		„	I	12	18	.42857	.47619
„	V	61	1(49)[1]	1	1	30	26	2		„	R	27	39	.45000	.45508
34	V	158		1	5	70	74	7	1	„	R	84	120	.53165	.47987
37	V	155			4	49	91	11		C	R	109	139	.70323	.40485
50	I + II	124			1	25	74	21	3	A	U	124	186	1.00000	.50407
„	III + IV	23				9	13	1		„	I	15	17	.65217	.32807
51	I + II	73				19	45	9		„	U	63	81	.86301	.36987
„	III + V	43			1	15	27			„	I	26	28	.60465	.29236
53	V	98			2	34	58	4		C	R	64	76	.65306	.35262
58	juv.	74			2	20	45	7		B	J	57	75	.77025	.42595
72	„	72				26	42	4		„	J	50	58	.69445	.32785
90a	„	61	1	0	1	21	36	2		A	J	36	54	.59016	.54592
91	II	101			1	25	59	13	3	„	U	93	139	.92079	.53367
„	III + IV	100			3	41	52	4		„	I	57	71	.57000	.38899
92	II	74			4	25	39	6		„	U	47	67	.63514	.50887
„	IV	50			3	25	19	3		„	R	22	34	.44000	.49633
93	II	50			1	17	30	2		„	U	33	39	.66000	.35143
94	I + II	49			1	23	24	1		„	U	25	29	.51021	.33843
„	V	50			3	25	20	2		„	R	21	31	.42000	.45265
96	juv.	74			2	24	37	11		C	J	57	83	.77027	.53554

[1]) These two observations omitted in calculating mean and variance as vertebrae possibly abnormal.

It cannot be too strongly emphasized that on no account must the partitioning of the individual variants be influenced by the values of the variants themselves. The idea of randomness as regards all effects other than those being examined, which is essential to any sound statistical tests such as those discussed, is entirely destroyed if this influence is allowed. For instance, in partitioning of counts of vertebrae, random selection is entirely upset if the counts are divided into area or ripeness groups chosen as giving differences in vertebral number. The area groups, ripeness groups, date groups, etc. must be chosen entirely without reference to the values of the variants. To do otherwise is to argue in a circle, definitely to make significant differences of which the significance is to be statistically tested. Naturally, if such partitioning be allowed, "significant" differences can always be "found", though they do not in reality exist.

Special applications of the Analysis of Variance to herring race problems will be dealt with as occasion arises. Table 1 gives, for each of Schnakenbeck's samples with which I have dealt, Schnakenbeck's serial reference number, the area group and ripeness group of the sample, n', the number in the sample, $S(x)$, the total excess count, in each sample, above 56, $S(x^2)$, the sum of the squares of $56 - x$, where x is any count, $\bar{x}$, the mean count, and s^2 the variance, calculated as follows

$$s^2 = \frac{S(x-\bar{x})^2}{n} = \frac{S(x^2) - \bar{x}\,S(x)}{n}$$

We may as well start our analysis by an examination of the distribution of the variances, s^2.

There are 48 samples, the grand mean,

$$\bar{\bar{x}} = \frac{2146}{3543} = .6057014$$

the total variance

$$s^2_t = \frac{3038 - 2146 \times .6057014}{3543 - 1} = .4907$$

the weighted mean variance

$$= \frac{SS(x_p - \bar{x}_p)^2}{S(n'_p - 1)}$$

is calculated by calculating $S(x^2) - \bar{x}\,S(x)$ for each sample, adding, and dividing the sum by the total number of counts minus the number of samples, viz. $3543 - 48$ $(= 3495)$. The result is .4705.

The observed variances will, if there are no significant differences of variability in the different classes, be distributed about the weighted mean $\bar{v}$ with variance

$$v_{\bar{v}} = \frac{2\bar{v}^2}{N} = \frac{4\bar{v}^2}{100} = .0088548$$

where N is the number of counts in a sample. As this number differs widely in the different samples and variance $\backsim \frac{1}{N}$, the number should be taken as equal to the harmonic mean of the numbers of counts in samples, i. e. approximately 50. The observed mean variance $\bar{v}_o = .4552$ and the observed variance of variance

$$\frac{S(v_o - \bar{v}_o)^2}{47} = .009084$$

It is obvious therefore, without applying the z-test that the variances do not differ significantly, but that all samples have the same variability within errors of random sampling. If this test does not satisfy, a Curve of Error may be fitted to the variances grouped in any convenient manner in a frequency distribution.

The distribution of variances has been somewhat emphasised, partly because equal varibility within samples is necessary for the application of the Analysis of Variance, and partly for another reason. Schnakenbeck has divided his samples of counts into frequency "types" differing somewhat widely. If a sample does not conform to a "type", he considers it a mixture of two "types". Such mixtures should be indicated by increased variance in the mixed samples. It can be said safely that no such mixtures are indicated by the samples.

Another way. to test this matter is to plot variances against means of corresponding samples. This has been done in Fig. 4. There should

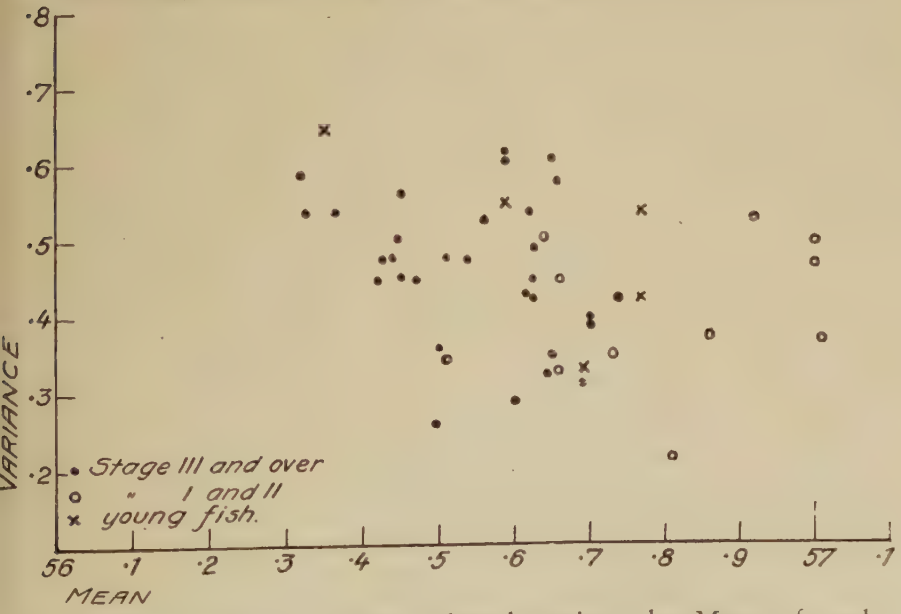

Fig. 4. Showing the Variance plotted against the Mean of each Sample of Vertebral Counts.

be a distinct drop at the ends in the plotted points and a hump in the middle, if the lower and higher means are *pure* racially and the intermediate means belong to mixtures. There is no sign of such an effect. The data do not justify the assumption of mixtures of races in any way. Fig. 4 appears to show a lower variance for stages I and II than for either the young or the mature fish. This difference is, however, when the z-test is applied, proved not to be significant.

We will now proceed to analyse the data on sound statistical lines, and first of all we shall investigate whether all the samples are homogeneous, or whether they differ significantly in their means. We have already proved that they do not differ significantly in any other way. The sums of squares are divided as shown i Table 2[1]).

Table 1 a.

Stage		Area A	Area B	Area C
		56.59	56.60	56.77
		56.59	56.58	56.77
	J		56.40	
			56.77	
			56.69	
		56.83	56.77	
		56.73	56.81	
		57.00	56.6	
	U	57.00	57.04	
		56.86	56.66	
		56.92		
		56.63		
		56.66		
		56.51		
		56.61	56.45	
		56.63	56.58	
	I	56.74	56.3	
		56.49	56.43	
		56.63		
		56.65		
		56.60		
		56.57		
		56.41	56.52	56.65
		56.47	56.65	56.62
		56.45	56.50	56.63
	R	56.36	56.69	56.62
		56.44	56.66	56.70
		56.42	56.43	56.65
			56.51	
			56.56	
			56.32	
			56.45	
			56.53	

[1]) See p. (28) for methods of calculation of these quantities.

Table 2.

	D. F.	SS	s^2
Within samples $= S(x_p - \bar{x}_p)^2$	3495	1644.2477	.4705
Between Means of samples $= Sn'_p(\bar{x}_p - \bar{\bar{x}})^2$	47	93.9171	1.9982
Total $= S(x - \bar{\bar{x}})^2$	3542	1738.1648	.4907

Obviously, without applying the z-test, there is a highly significant difference between means of samples, the values .4705 and 1.9982 being obviously significantly different.

We must now search for possible causes of the difference between means. "Area" and "Stage of Maturity" suggest themselves as being likely causes.

The samples fall naturally into three areas (A) North of line, Firth of Forth to the Skaw, (B) Between this line and a line from the Wash to Texel, (C) Flemish Bight Area. The positions at which the samples were taken are shown roughly on S c h n a k e n b e c k's chart, Abb. 42. The stages of ripeness chosen are "J", young fish, "U", fish in stages I and II, "I", in stages III, III and IV, or III to V, "R" in stages IV and V, V, VI or VII.

Table 1 indicates, by a pair of letters in each case, how each sample has been classified, and Table 1a shows the mean of each sample in each subclass as well as the general mean of each subclass, the latter underlined, to illustrate the order of differences which we are investigating.

We now form a 4×3 table as below (Table 3) in which under n' in each case is given the total number of counts in each cell, $S(y)$ gives the total excess above 56 vertebrae, Y, a "corrected mean" and $S(Y)$, a value for the total excess calculated according to a method detailed below. Of the marginal symbols and figures, n'_a, n'_j etc. give the numbers of counts in columns and rows respectively, $S(y_j)$, $S(y_a)$ etc. the total corresponding excesses above 56 and $\bar{y}_a$, $\bar{y}_j$ etc. the mean excesses. In the corner is given the complete total of counts n'_t, the complete total excess $S(y_t)$ and the grand mean of all counts (as an excess above 56) $\bar{y}_t$ or $\bar{\bar{y}}$.

We now have to find out whether the excessive variance between means of samples may be accounted for by direct effects of area and ripeness. The problem is really to fit a multiple regression of count on area and ripeness, and it is desirable, at any rate at first, to fit the simplest possible regression, that is to say, to find out whether the change in vertebral count is quite simply related to the variations of area and ripeness. Ordinary regression equations are fitted on the assumption that the independent variables vary continuously, and that their scale is known. Obviously the scales of both area and ripeness

Table 3.

	A	B	C	
	11	21	31	
J	$n' = 61$ $S(y) = 36$ $S(Y) = 35.537$ $Y = .58257$	$n' = 297$ $S(y) = 179$ $S(Y) = 179.848$ $Y = .60554$	$n' = 74$ $S(y) = 57$ $S(Y) = 56.614$ $Y = .76505$	$n'_j = 432$ $S(y_j) = 272$ $\bar{y}_j = .62963$
	12	22	32	
U	$n' = 517$ $S(y) = 427$ $S(Y) = 419.958$ $Y = .81230$	$n' = 109$ $S(y) = 84$ $S(Y) = 91.043$ $Y = .83526$	$n' = 0$ $Y = .99476$	$n'_u = 626$ $S(y_u) = 511$ $\bar{y}_u = .81629$
	13	23	33	
I	$n' = 405$ $S(y) = 249$ $S(Y) = 232.988$ $Y = .57528$	$n' = 107$ $S(y) = 48$ $S(Y) = 64.012$ $Y = .59824$	$n' = 0$ $Y = .75775$	$n'_i = 512$ $S(y_i) = 297$ $\bar{y}_i = .58008$
	14	24	34	
R	$n' = 453$ $S(y) = 187$ $S(Y) = 210.515$ $Y = .46471$	$n' = 804$ $S(y) = 416$ $S(Y) = 392.103$ $Y = .48769$	$n' = 716$ $S(y) = 463$ $S(Y) = 463.388$ $Y = .64719$	$n'_r = 1973$ $S(y_r) = 1066$ $\bar{y}_r = .54029$
	$n' = 1436$	$n'_b = 1317$	$n'_i = 790$	$n'_t = 3543$
	$S(y_a) = 899$	$S(y_b) = 727$	$S(y_c) = 520$	$S(y_t) = 2146$
	$\bar{y}_a = .62604$	$\bar{y}_b = .55201$	$\bar{y}_c = .65823$	$\bar{y}_t = \bar{\bar{y}} = .60570$
				$\bar{\bar{y}}\, S(y_t) = 1299.83520$

are indeterminate, and we are limited to the allowance of all or none of the effect of these variables in determining vertebral number. In short, if *a*, *b*, *c*, give the effects of the areas A, B, C, and *j*, *u*, *i*, *r*, give the effects of the ripeness stages J, U, I and R, in the multiple regression equation in these variables

$$y = m_0 + m_1 a + m_2 b + m_3 c + \ldots\ldots$$

the coefficients of *a*, *b*, *c* etc. are in every case either unity or zero.[1]) The regression is therefore not linear but might be called a "point" regression.

In the usual experimental work to which the Analysis of Variance is applied, the experiments are so arranged that the numbers of

[1]) In regression equations it is usual to use the symbol y for the dependent variable. I have adhered to this procedure in the later part of this paper. The symbol y has precisely the same meaning as x in the earlier analysis, i. e. it measures the excess of a single count above 56 vertebrae.

observations in each cell in such a table as Table 3 are equal. In this case the total sum of squares between means in cells,

$$S_{11}^{34} n'_p (\bar{y}_p - \bar{\bar{y}})^2$$

may be analyzed into three parts as follows:—

$$S_{11}^{34} n'_p (\bar{y}_p - \bar{\bar{y}})^2 =$$

$$S_a^c n'_p (\bar{y}_p - \bar{\bar{y}})^2 + S_j^r n'_p (\bar{y}_p - \bar{\bar{y}})^2$$

$$+ S_{11}^{34} n'_p (\bar{y}_{11} - \bar{y}_{a, b \text{ or } c} - \bar{y}_{j, u, i \text{ or } r} + \bar{\bar{y}})^2$$

in which equation, the terms on the right are summed for every row and every column, the suffixes being those which apply to the particular cell being summed. The first term on the right gives the sum of squares of the weighted means of the rows about the general mean, the second term a similar sum for the columns and the third term gives the residual sum of squares. We may look upon this analysis in another way. We wish to represent the mean values of counts in each cell as nearly as possible by adding to or subtracting from the general mean an amount due to area and another due to age or ripeness, and we are using the mean effects of these variables as giving the best estimates of the effects. Thus the mean effect of A is

$$.62604 - .60570 \text{ and that of J is } .62963 - .60570$$

The value calculated for cell 11 is therefore

$$.60570 + (.62604 - .60570) + (.62963 - .60570)$$
$$= .62604 + .62963 - .60570$$

The *total* residual between the actual value 36 and the calculated value is thus

$$36 - 61\ (.62604 + .62963 - .60570) = Sn'_{11} (\bar{y}_{11} - \bar{y}_a - \bar{y}_j + \bar{\bar{y}})$$

and the sum of these quantities over all cells, squared, and divided by the appropriate number of degrees of freedom gives the residual variance of the weighted cell means about the general mean, after the variance due to area and ripeness effects has been eliminated.

The best way to calculate these quantities is as follows. The total sum of squares of all weighted cell means about the general mean,

$$S_{11}^{34} n'_p (\bar{y}_p - \bar{\bar{y}})^2$$

is first found, by calculating, for each cell,

$$\bar{y} S(y) \qquad \frac{S(y)}{n'} S(y)$$

and adding the products, finally subtracting $\bar{\bar{y}} S(y_t)$ to correct to the grand mean.

$S_a^c (\bar{y}_{a, b, c} - \bar{\bar{y}})^2$ is found by finding for each column $\bar{y} S(y)$ and subtracting, as before, $\bar{\bar{y}} S(y_t)$, and similarly for the rows. We have then as a final result:—

Table 4.

	D. F.	SS.	s^2
$S_a^c n'_p (\bar{y}_p - \bar{\bar{y}})^2$	2	6.56563	3.28281
$S_j^r n'_p (\bar{y}_p - \bar{\bar{y}})^2$	3	36.78125	12.26041
$S_{11}^{34} n'_p (\bar{y}_{11} - \bar{y}_{a \text{ to } c} - \bar{y}_{j \text{ to } r} + \bar{\bar{y}})^2$.	4	13.71016	3.42754
$S_{11}^{34} n'_p (\bar{y}_p - \bar{\bar{y}})^2$	9	57.05704	

The residual is found by subtracting the first two sums from the last. As there are two empty cells and the grand mean is calculated from the data, there are 9 degrees of freedom altogether. The grand mean also absorbs one degree in the case of the first two terms, leaving 4 for the residual. All of the above estimates of variance would undoubtedly be found by the z-test significantly different from that found between means of samples *within* cells, viz. 1.9982. The matter, however, is complicated by the fact that the counts are *not* equal in all cells, two cells even having no counts at all. Thus the effect of C is heavily weighted by the effects of A and B, and so on. If the calculated values for the cells are substituted for the real values, the calculated marginal totals do not conform to the actual totals, and this is manifestly not as it should be. The arrangement is what is known as non-orthogonal between the variables, one set being correlated with the other by reason of unequal representation. In such cases, the means as hitherto used are *not* the best estimates of the effects and the residual sum of squares is not a minimum, as would be the effect if the "best-fitting" constants were employed. To digress for a moment, it will be noticed that I have here used the term "constants" in place of "variables". The former is perhaps preferable since, the coefficients being always unity or zero, the numbers do not vary in the usual sense.

Observational data nearly always show non-orthogonal arrangement. Though there is no way of *eliminating* non-orthogonality of effects, it can be minimised and valuable information extracted from data showing such effects. Mr. Y a t e s very kindly introduced the following method to my notice and gave me much help in its use.

We wish to fit an equation of the form

$$y = m + b_0 a + b_1 b + b_2 c + b_3 j + b_4 u + b_5 i + b_6 r$$

to *every* observation in each cell, where m is a particular kind of mean, constant for each observation (vertebral count), and the other constants, a, b, c, j etc. represent the effect of the areas A, B, C etc., the ripeness stages J, etc. The fit is to be such that the sum of the residuals from the calculated values is a minimum. It should be noticed once more that the equations differ from ordinary equations in that the constants either occur or not, that is to say, the values of b_0, b_1, b_2 etc. are always either unity or zero.

We have thefore
n'_{11} equations,

$$m + 1a + 1j + 0b + 0c + 0u + 0i + 0r = y$$

n'_{12} equations

$$m + 1a + 0j + 0b + 0c + 1u + 0i + 0r = y$$

and so on.

If all these equations are written down and the Method of Least Squares applied, that is to say, the partial differentials of

$$S\,(b_0m + b_1a + b_2b + b_3c + b_4j + b_5u + b_6i + b_7r - y)^2$$

with respect to the different constants equated to zero, the resulting normal equations are

$$\begin{gathered} m\,(n'_t) + a\,(n'_{11} + n'_{12} + n'_{13} + n'_{14}) + b\,(n'_{21} + n'_{22} + n'_{23} + n'_{24}) \\ + c\,(n'_{31} + n'_{32} + n'_{33} + n'_{34}) + j\,(n'_{11} + n'_{21} + n'_{31}) \\ + u\,(n'_{12} + n'_{22} + n'_{32}) + i\,(n'_{13} + n'_{23} + n'_{33}) + r\,(n'_{14} + n'_{24} + n'_{34}) \\ = S\,(y_t) \end{gathered}$$

and so on, the complete set, using the notation indicated in Table 2 is as follows: —

$$\begin{aligned}
&m(n'_t) + a(n'_a) + b(n'_b) + c(n'_c) + j(n'_j) + u(n'_u) + i(n'_i) + r(n'_r) = S(y_t) \\
&m(n'_a) + a(n'_a) + b(0) + c(0) + j(n'11) + u(n'12) + i(n'13) + r(n'14) = S(y_a) \\
&m(n'_b) + a(0) + b(n'_b) + c(0) + j(n'21) + u(n'22) + i(n'23) + r(n'24) = S(y_b) \\
&m(n'_c) + a(0) + b(0) + c(n'_c) + j(n'31) + u(n'32) + i(n'33) + r(n'34) = S(y_c) \\
&m(n'_j) + a(n'11) + b(n'21) + c(n'31) + j(n'_j) + u(0) + i(0) + r(0) = S(y_j) \\
&m(n'_u) + a(n'12) + b(n'22) + c(n'32) + j(0) + u(n'_u) + i(0) + r(0) = S(y_u) \\
&m(n'_i) + a(n'13) + b(n'23) + c(n'33) + j(0) + u(0) + i(n'_i) + r(0) = S(y_i) \\
&m(n'_r) + a(n'14) + b(n'24) + c(n'34) + j(0) + u(0) + i(0) + r(n'_r) = S(y_r)
\end{aligned}$$

Substituting the appropriate values of n' in above, we have

$$\begin{aligned}
&m(3543) + a(1436) + b(1317) + c(790) + j(432) + u(626) + i(512) + r(1973) = 2146 \\
&m(1436) + a(1436) + j(61) + u(517) + i(405) + r(453) = 899 \\
&m(1317) + b(1317) + j(297) + u(109) + i(107) + r(804) = 727 \\
&m(790) + c(790) + j(74) + u(0) + i(0) + r(716) = 520 \\
&m(432) + a(61) + b(297) + c(74) + j(432) = 272 \\
&m(626) + a(517) + b(109) + c(0) + u(626) = 511 \\
&m(512) + a(405) + b(107) + c(0) + i(512) = 297 \\
&m(1973) + a(453) + b(804) + c(716) + r(1973) = 1066
\end{aligned}$$

The last four equations give, respectively, j, u, i and r in terms of m, a, b and c, thus

$$432j = 272 - 432m - 61a - 297b - 74c$$

$$j = \frac{272 - 432m - 61a - 297b - 74c}{432}$$

Working these values out and adding them all in turn to the coefficients already given for m, a, b and c, we find that the coefficients for m are zero in all equations, leaving the following three equations only for solution.

$$+ 576.034a - 401.196b - 174.843c = -41.120$$
$$- 401.195a + 743.843b - 342.646c = -45.437$$
$$- 174.843a - 342.647b + 517.488c = 86.557$$

It will be seen that these are here really only two equations, since the sum of all three is zero in each term.

Putting, therefore,

$$a + b + c = 0 \quad \text{or} \quad a = -b - c$$

we have
$$977.230b + 750.877c = 41.120$$
$$1145.037b + 58.549c = -45.437$$

giving

$$b = -.04551$$
$$c = +.11399$$
$$a = -.06848$$

Substituting these values in the last four of the original eight equations, we have

$$r + m = .53320$$
$$i + m = .64376$$
$$u + m = .88077$$
$$j + m = .65106$$

and since $r + i + u + j = 0$

$$m = +.67720$$
$$r = -.14400$$
$$i = -.03344$$
$$u = +.20357$$
$$j = -.02614$$

In non-orthogonally arranged data the "best" expected value is given by fitted constants as just calculated.

The "best" mean value for cell (11) is

$$m + a + j$$

and the best value for the expected total excess is

$$n'_{11}(m + a + j)$$

and so on for the other cells. The constant m is equal to the value which the grand mean would have if there were an equal number of counts in each cell.

The further analysis takes the following form (Table 5). Methods of calculating the various sums of squares are given after the table. To exhibit the whole analysis in one place Table 2 has been repeated here, with remarks on significance of variance differences shown.

Analysis of Variance

	D.F.	SS.	s^2
Within all samples $= S\,(y_p - \bar{y}_p)^2$	3495	1644.2477	.4705
Between means of all samples $= Sn'_p\,(\bar{y}_p - \bar{\bar{y}})^2$	47	93.9171	1.9982
Total $= S(y - \bar{\bar{y}})^2$	3542	1738.1648	.4907

There is highly significant difference between means of samples.

Fit constants *a*, *b*, *c* for areas; *j*, *u*, *i*, *r* for stages of age and maturity.

Further Analysis (Table 5).

	D.F.		SS	s^2	z[1]	
Between means of cells (about arbitrary working mean of 56) $= S_{11}^{34} n'\,(\bar{y}^2)$	10	(1)	1356.89224			
Calculated residuals from values calculated from constants $= S_{11}^{34} n'_p\,(\bar{y}_p - Y_p)^2$	4	(2)	6.38393	1.596		$z = .249$ (not significant)
Removed by constants and general mean $(\bar{\bar{y}})$	6	(3)	1350.50831			
Removed by $\bar{\bar{y}}$ [and $= \bar{\bar{y}}\,S\,(y_t)$]	1	(4)	1299.83520			
Removed by constants	5	(5)	50.67311	10.135	**	
Between means of samples within cells $= S_{11}^{34}\, n'_s\,(\bar{y}_s - \bar{y}_p)^2$	38	(6)	36.85706	.970		
(2) + (5) + (6) $= S\,n'_p$ $(\bar{y}_p - \bar{\bar{y}})^2$ (for check)	47	(7)	93.9141			$z = .3617$**
Within samples	3495	(8)	1644.2477	.4705		

(1) $(\bar{y}_{11})^2$ is the square of the mean of all vertebral counts in cell 11, measured from 56 vertebrae.

$$n'_{11}\,(\bar{y}_{11})^2 = n'_{11}\left(\frac{S\,(y_{11})}{n'_{11}}\right)^2 = \bar{y}_{11}\,S\,(y_{11}) = A$$

$$S_{11}^{34} n'\,(\bar{y})^2 = S\,(A)$$

over all cells. There are twelve cells but in two of them no samples occur.

(2) The corrected means Y_{11}, Y_{12} etc. are given by the sum of the constants appertaining to cell 11, 12, etc. + m for each cell.

[1]) When the observed value of z lies beyond the 5 % point of the z-distribution it is marked with one asterisk, if beyond the 1 % point, with two asterisks.

$\bar{y}_{11} = \frac{S(y_{11})}{n'_{11}}$. Thus $S_{11}^{34} n_p (\bar{y}_p - Y_{11})^2$ is obtained by squaring the difference between $\frac{S(y)}{n'}$ and Y and multiplying by n' for each cell. Since m is dependent on the values of the other constants, and since $a + b + c = 0$ and $j + u + i + r = 0$, 5 *independent* constants have been calculated from the data. Furthermore $S(\bar{y}_t) = S(Y_t)$, over all cells. Thus there are only 10—6 degrees of freedom for

$$S_{11}^{34} n'_p (\bar{y}_p - Y_p)^2$$

(3)[2]) SS = (1) — (2). Most of this variance is due to $S(y_t)^2$ being calculated about 56, instead of about $\bar{\bar{y}}$, the grand mean.

(4) is due to correction for the mean, i. e. to subtracting $\bar{\bar{y}}\, S(y_t)$ from $S(y_t)^2$, $S(y_t)$ and $S(y_t)^2$ referring here to the total excesses of counts above 56 vertebrae.

(5) SS = (3) — (4).

(6) The variances of the weighted means of each sample about the general mean of the cell in which the sample occurs. If $y_{s\,11}$ is any count in sample **S** of cell 11 and if $\bar{y}_{11}$ is the general mean in cell 11 and $= \frac{S\,S(y_{s\,11})}{S(n'_{11})} = \frac{S(y_{11})}{S(n'_{11})}$ and $\bar{y}_{s\,11}$ the mean of sample **S** in cell 11 and $= \frac{S(y_{s\,11})}{n'_{s\,11}}$

We have

$$Sn'_{s\,11} (\bar{y}_{s\,11} - \bar{y}_{11})^2 = Sn'_{s\,11} [\bar{y}_{s\,11} (\bar{y}_{s\,11} - \bar{y}_{11}) - \bar{y}_{11} (\bar{y}_{s\,11} - \bar{y}_{11})]$$

which, since the term

$$Sn'_{s\,11} \bar{y}_{11} (\bar{y}_{s\,11} - \bar{y}_{11}) = 0, \text{ over all samples,}$$

$$= Sn'_{s\,11} [\bar{y}_{s\,11} (\bar{y}_{s\,11} - \bar{y}_{11})]$$

$$= Sn'_{s\,11} \left[\left(\frac{S(y_{s\,11})}{n'_{s\,11}} \right)^2 - \frac{S(y_{s\,11})}{n'_{s\,11}} \frac{SS(y_{s\,11})}{Sn'_{11}} \right]$$

$$= S(\bar{y}_{s\,11} \cdot Sy_{s\,11}) - SS(y_{s\,11}) \frac{SS(y_{s\,11})}{Sn'_{11}} = S[\bar{y}_{s\,11} S(y_{s\,11})] - S(y_{11}) \bar{y}_{11}$$

$Sn_{s\,11} (\bar{y}_{s\,11} - \bar{y}_{11})^2$ is therefore calculated by multiplying in each sample in cell 11, the total excess by the average excess, adding the results and subtracting the product of the total excess and average excess for the cell. This is calculated for every cell and the sum found. The mean being, for every cell, calculated from the data, the degrees of freedom are for every cell one less than the number of samples in the cell. This reduces the original degrees of freedom between samples, which were 48 before correction for the grand mean, by 10.

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[2]) For an alternative method, analogous to the method used in the Analysis of Variance with orthogonal data see Appendix 5.

(7) Calculated by finding $\bar{y}S(y)$ for each *sample*, adding, and subtracting $\bar{\bar{y}}S(y_t)$ from the sum.

(8) The calculation of this quantity has already been explained (p (33)).

The allotting of the degrees of freedom to the various fractions of the total sum of squares offers some difficulty at first in the use of the Analysis of Variance. The matter is much simplified, however, if the rule is borne in mind, that the calculation, from the data themselves, of every independent constant which is used in fitting calculated values, reduces the original number of degrees of freedom by unity. Such constants may be totals, means, subtotals, submeans, or other constants such as those used in the present analysis. Our working mean of 56 vertebrae was *not* calculated, and of course absorbs no degrees of freedom from the data.

The analysis is now complete and ready for tests of significance of differences between estimates of variance. Significance of difference between means of non-classified samples has already been found to exist. Comparing (5) and (6), it is obvious that the effects of area and maturity are together highly significant. The z-test is quite unnecessary here.

Comparison of (2) and (6). The *additive* effects of area and maturity would be exactly represented by the constants (5) were it not for the variance between means of samples in each cell. The variance between corrected means (2) will therefore not differ *significantly* from that between means within cells, if the effects of area and ripeness are purely additive. The value of z for the two estimates of variance in question is well within the 5 % point of the z-distribution for $n_1 = 4$, $n_2 = 38$, and the two estimates are therefore not significantly different. The effects are therefore additive. Maturity has no greater effect in one area than in another. Area shows no more effect at one stage of ripeness than another. Since non-orthogonality has been as far as possible eliminated by the fitting of combined constants, and since there is no interaction between the effects, the most efficient estimate of each effect taken separately is given by subtracting, from the variance ascribable to the combined effects, that due to the remaining effect taken separately. The analysis is therefore as follows:—

	D. F.		SS.	s^2	
Combined effects (5) Table 5	5		50.67311		
Maturity taken alone (Table 4)	3		36.78125		
Area alone	2		13.89186	6.9459	**
(6) Table 5 ("Error")	38	(1)	36.85706	.970	**
Combined effects	5		50.67311		
Area alone (Table 4)	2		6.56563		**
Maturity alone	3		44.10748	14.7025	

Age and maturity alone and also area alone produce such high variances that the *z*-test is unnecessary. It will be seen that the estimates of variance due to effects of maturity and area, obtained by the above method of subtraction, are much higher than those obtained by the ordinary Analysis of Variance as used for Table 4. The former may be either the higher or the lower, depending on whether one effect is enhanced or masked by unequal representation in the classification in terms of the other effect. In Table 3, for instance, the directly calculated effect of C, which, even as it stands, gives a higher mean vertebral count than either A or B, is masked by not being represented in the cells for U and I, U in particular giving a very high mean, though masked by absence in the C cell. The enhanced values for the effects given by the method of subtraction are therefore in accordance with common sense.

We find then that the herrings in the three areas chosen differed significantly in their vertebral count, whatever their classification in age or stage of maturity; also that herrings differing in their age or stage of maturity differed in their vertebral count, in whichever of the three areas they were taken.

Though classified in these two ways, the samples in cells are still not homogeneous in their means, since there is a significant difference between (6) and (8) of Table 5. I do not, however, consider further subdivision into areas or stages of age and maturity justifiable with the present data. For instance, if a sub-classification by divisions of longitude were attempted, there would be very many empty cells. The data would become unmanageably non-orthogonal. They are not sufficiently extensive to stand further sub-classification.

Though vertebral number has now been proved by sound statistical methods to vary with area, the data are not capable of showing whether it is possible to aggregate this variation towards certain definite centres so as to define a given number of actual races. It appears probable that the variation is continuous. If this is so, it would account probably for the remaining heterogeneity within cells. The data certainly do not justify the assumption that a very limited number of definite races exist which overlap each other in area.

The variation due to age and maturity is highly significant. It is, however, impossible to *explain* this variance in any simple terms. The classification into age and maturity classes has been used here for the purpose of elimination of a source of error in comparing areas, and has not been approached as of interest in itself. A further sub-classification by time of taking samples would be necessary for this examination, and this would leave an absurdly few samples in each cell of the manifold classification. Age, too, would have to be separated from maturity, since the J fish are younger than the rest, while many of the U, I and R fish may be of similar age, one to another. The very high variance due to the classification into age and maturity does, however, serve the purpose of emphasizing the great importance

of comparing only fish of the same stage of maturity in examining area differences.

I do not consider that the data dealt with are capable of yielding further information than this, that there is a very significant area difference in vertebral number. This may actually be stronger than is indicated by the data, since the fact that the samples were not taken simultaneously in the three areas would certainly tend to obscure the area effect. The variance due to difference in stage of maturity, which undoubtedly would be significant even if the stage J were omitted, is very *suggestive*. The purposes of modern statistical methods, however, are these, (1) To discover the probability that observed effects might have arisen by chance, (2) To measure these effects if found significant. The correctness of conjecture can be tested statistically only when the data can be classified according to certain preconceived hypotheses and, *when so classified,* are sufficiently extensive for analysis. It is obvious that in the present case they are not sufficiently extensive. It is quite impossible to test, with the present data, the hypothesis that the variation due to stage of maturity is due in each area to mixture of one "race" of herrings of a certain maturity with another at a different stage of maturity. It is possible that, with access to all the vertebra data at present extant, it might be possible to test such a hypothesis. It is unlikely, however, since their classifications probably would not be sufficiently orthogonal for the various effects to be disentangled. It would be preferable to use the suggestions offered by all the data extant as hypotheses to be tested by further data collected specially with this end in view, extreme care being taken that each sub-classification group be as equally as possible represented in each cell of each other sub-classification group. Such a collection of data would not be impossible if everyone interested were to combine in its collection. It would very probably solve once and for all the herring race question.

Summary.

S c h n a k e n b e c k's empirical methods for distinguishing herring races by their vertebral counts are criticised. F i s h e r's Method of Maximum Likelihood has been employed for finding the best-fitting Curve of Error to fit certain of S c h n a k e n b e c k's frequency distributions of vertebral counts. These being very highly grouped, the usual method of fitting by moments is shown to be inefficient. The samples tested are shown not to differ significantly from samples from a highly grouped normal population. Differences in "mode of variability" found by S c h n a k e n b e c k are ascribable entirely to the varying position of the mean in the group interval. The method for finding the best-fitting Curve of Error for highly grouped data is described in detail, with an example, and graphs are given to aid in its use. F i s h e r's method of the Analysis of Variance has been

employed to test the significance of the influence of area and age and ripeness on vertebral count. A method has been described in detail for dealing with data in which counts classified according to one scheme are unequally represented in the compartments of another scheme of classification, and the necessary allowance for the effects of this non-orthogonality are discussed.

A full introduction to the principles underlying the Analysis of Variance has been included.

The distribution of variance in the samples is found not to differ significantly from the normal distribution, indicating that the samples with intermediate "modes of variability" are not mixtures but intermediate in character between Schnakenbeck's "types".

The influence of area in determining vertebral number is shown to be significant but less so than that of stage of ripeness, which is highly significant and independent of area. This cannot be simply explained and is used here merely as a means of eliminating an important source of error in testing the area effect. There is no evidence of the existence of any given *number* of races as defined by mean vertebral number. Vertebral number may vary *continuously* with area. The data analyzed are only a part of those dealt with by Schnakenbeck, and the inclusion of the remainder might modify the results of the analysis. The paper must be looked upon mainly as an introduction to certain powerful weapons of statistical research, which are of great service not only in analysis of results, but also as a guide in choosing schemes for the collection of data so that they may yield the maximum amount of information.

List of Papers Referred To.

(1) Schnakenbeck, W. "Zum Rassenproblem bei den Fischen". Zeitschrift für Morphologie und Ökologie der Tiere. 21. Band, 3/4 Heft. Julius Springer, Berlin, 1931.

(2) Fisher, R. A. "On the Mathematical Foundations of Theoretical Statistics". Phil. Trans. Royal Society, A, CCXXII, 309—368. (Obtainable as an offprint from the Secretary, Royal Society, price 7/0).

(3) Fisher, R. A. "Theory of Statistical Estimation". Proceedings of Cambs. Phil. Soc., Vol. XXII, Part 5 Cambridge University Press, July, 1925.

(4) Fisher, R. A. "Statistical Methods for Research Workers". Third Edition. Oliver & Boyd, London, 1930.

Appendix 1:

Glossary of Terms.

Variance. Variance in the hypothetical population from which a sample is assumed to be drawn is denoted by σ^2 and is the square of the Standard Deviation of the whole

population. Variance of a sample which is denoted by s^2 is an *efficient* (see below) estimate of σ^2, if the sum of squares of which it is the mean is divided by the number of degrees of freedom pertaining to the sample values, and not by the total number of the sample values.

A Consistent Estimate or Statistic of any parameter such as the mean or standard deviation of a hypothetical population from which a sample is drawn in an estimate which tends to equality with the parameter as the sample is increased, becoming equal to it for the whole population. The mean, standard error or variance as calculated from the corrected moments of a sample are consistent estimates if the sample is not highly grouped, but inconsistent in highly grouped data.

Degrees of Freedom. In calculating variance the sum of squares from which it is to be calculated must be divided by the Degrees of Freedom in which a sample value is free to vary conformably with a given number of independent fixed relations between the values. In applying the χ^2 test, the term degrees of freedom means the number of ways in a sample in which an observed frequency may differ from a calculated frequency conformably with a given number of independent fixed relations between the frequencies. Thus the mean value as calculated from data fixes one relation between the data, in that, the mean being fixed, all the frequencies but one may vary freely, but the last is fixed. A calculated total and a calculated standard error or variance fix other relations. Each *independent* constant which is calculated from the data absorbs a degree of freedom. When any marginal total of calculated values is made to agree with an observed marginal total, a degree of freedom is absorbed by the calculated values concerned.

The Efficiency of an Estimate or Statistic of any parameter such as the mean and standard deviation of a normal distribution is the percentage of information inherent in the data, relevant to the parameter in question, of which the estimate makes use. An estimate calculated by the Method of Maximum Likelihood has 100 % efficiency and the efficiency of any other statistic may be estimated by comparison with the Maximum Likelihood value. An estimate may be consistent, but not efficient. Thus the median is a consistent estimate of the mean of a normal distribution, since they agree in the whole normal hypothetical population, but the

median of a sample is a less efficient estimate of the mean of the hypothetical best-fitting normal distribution than is the mean as usually calculated. See Fisher (2).

Appendix 2:

On the Standard Error of the "Corrected Mean" in any cell of Table 3.

The root of the residual variance after fitting constants, viz. 1.596, is the mean standard error of the corrected means in the different cells. The variance of any given corrected mean may be found, if desired, by finding the variance of each constant, the sum of which is the corrected mean in question. To find the variance of each constant, it is necessary to solve the equations on page (35) with substitution, in place of the numerical terms on the right hand side, of

1, 0, 0, 0, 0, 0, 0, 0
0, 1, 0, 0, 0, 0, 0, 0
0, 0, 1, 0, 0, 0, 0, 0 etc.

and obtaining the minors c_{11}, c_{12} and so on, as solutions of these eight sets of equations. The method is given in Fisher (4) p. 135. The standard deviation of b_1 on that page is $s\sqrt{c_{11}}$. The procedure is not as tedious as would appear at first sight. In the present case it is of little interest either to test the significance of each constant separately, or to test the significance of the difference between any given pair of corrected means, since the effect of each *set* of constants has been proved significant, taken as a whole. This is the chief beauty of the method of Analysis of Variance — that it takes into account the *sampling distribution* of constants of the same kind. It makes use of the whole of the relevant information contained in the data. The test of the difference between any given pair of constants or corrected means involves neglect of the information afforded by the data as to the sampling distribution of this difference. For instance, maturity effect may be really significant as a whole. Owing to random sampling effect, however, the maturity effect may not appear significant if tested between a given pair of corrected means. In the case given in Fisher (4), the variables corresponding to our constants are of radically different kinds, and therefore it is necessary to test the significance of each separately.

Appendix 3:

Note on the χ^2 test.

The χ^2 test is an approximate test only. It is assumed that the random sampling distribution of a calculated frequency in any class is normal, whereas it conforms actually more nearly to the Poisson Series. When the mean of a Poisson Series is a fairly high number,

the mean and the mode agree nearly in position, but when the mean is low, the distribution is very skew. In using the test, the calculated number in each class is assumed to be the mean number in the class, and the distribution is assumed to be a normal one with variance equal to the mean. Thus with calculated frequency of 4, the standard error being 2, the normal distribution would contain a considerable proportion of negative frequencies, while the Poisson Series to which the actual distribution conforms is of course limited by zero. It is interesting to compare the proportional frequencies occurring with the normal distribution and the Poisson Series. With a mean and variance of 4 we have the following, considering, in the normal, that a value of ξ between 0 and $.5 = 0$, between .5 and $1.5 = 1$ and so on.

	Frequency of							
	Negative	0	1	2	3	4	5	5+
Normal ..	.0228	.0173	.0655	.1210	.1747	.1974	.1747	.2266
Poisson ..	Nil	.0183	.0733	.1466	.1954	.1954	.1563	.2147

It will be seen therefore that with a mean of 4 the Poisson Series gives considerably higher expectation of frequencies below the mean value than does the normal distribution, and inversely in the case of frequencies at or above the mean value. The most likely frequency to turn up is not 4 as in the normal distribution. The frequency 3 is equally probable. The effect is of course even stronger than that shown with mean frequency below 4. Thus the calculated value of χ^2 for a low cell-frequency is too great when the observed is less than the calculated frequency, and *vice versa*. In the samples to which the χ^2 test has been applied in the present paper, the observed are lower than the calculated frequencies in the end groups in nine cases out of ten, and we may be fairly certain therefore that the calculated χ^2 is at any rate not *under*-estimated in these cases.

Appendix 4:

Note on a Useful Check on Tabulated Values of the Ordinates and Areas of the Normal Frequency Distribution.

The equation to the Curve of Error may be written

$$z = e^{a + bx + cx^2} \text{ or } \log_e z = a + bx + cx^2$$

the values for the logarithm of z therefore lying on a parabola. Their second differences will therefore be constant, and we may write

$$\log z_1 + \log z_3 - 2 \log z_2 = \text{a constant}$$

$$\text{or } \frac{z_1 \cdot z_3}{z_2^2} = \text{a constant} \quad \text{or} \quad z_3 = \frac{z_2^2}{z_1} \cdot \text{a constant}$$

Thus if we calculate two equidistant values of z, a whole series of equidistant values may readily be obtained. This furnishes a very useful check on tabulated values, though there is of course a cumulative error owing to insufficiency of decimal places in the tabulated values, which renders the check inaccurate if used for a long series. The check may also be used in the case of tabulated areas. Though, here, the logarithms of the values do not of course conform exactly to a parabola, yet, if the values of $\frac{p_1 \cdot p_3}{p_2^2}$ be written down and differenced, it is found that the second differences of these values change very slowly and regularly and any errors in the tabulated values of p are at once shown up by irregularities in these second differences. The test is very sensitive and it brought to light several inaccuracies in the latter part of Burgess's Tables, though some of them were extremely small.

Appendix 5:

Method for Direct Calculation of the Variance ascribable to the Regression Constants, giving the Residual Variance by Subtraction.

In the ordinary Analysis of Variance with orthogonally arranged data, the variance between means of classes is given by

$$Sn'_p\,(\overline{y}_p - \overline{\overline{y}})^2, \text{ which in the present data}$$
$$= S_a^c\,[\overline{y}_p\,S\,(y_p)] + S_j^r\,[\overline{y}_p\,S\,(y_p)] - 2\overline{y}_t\,S\,(y_t)$$

in which the variance due to each separate set of constants a to c and j to r is given by

$$S_a^c\,[\overline{y}_p\,S\,(y_p)] - \overline{y}_t\,S\,(y_t) \text{ and}$$
$$S_j^r\,[\overline{y}_p\,S\,(y_p)] - \overline{y}_t\,S\,(y_t)$$

These expressions in expanded form are

$$\overline{y}_a\,S\,(y_a) + \overline{y}_b\,S\,(y_b) + \overline{y}_c\,S\,(y_c) - \overline{y}_t\,S\,(y_t) \text{ and}$$
$$\overline{y}_j\,S\,(y_j) + \overline{y}_u\,S\,(y_u) + \overline{y}_i\,(Sy_i) + \overline{y}_r\,S\,(y_r) - \overline{y}_t\,S\,(y_t)$$

With non-orthogonally arranged data the variance "between corrected means", of which that for cell 11 is $m + a + j$, that for cell 21 is $m + b + j$ and so on, is given by

$$(m + a + j)\,S\,(y_{11}) + (m + b + j)\,S\,(y_{21}) + \ldots\ldots - \overline{y}_t\,S\,(y_t)$$

If the corrected means for all cells be written down in this form the total sum of squares "between corrected means" is seen to be

$$mS\,(y_t) + aS\,(y_a) + bS\,(y_b) + cS\,(y_c) + jS\,(y_j) + uS\,(y_u)$$
$$+ iS\,(y_i) + rS\,(y_r) - \overline{y}_t S\,(y_t)$$

This variance cannot be split into two parts, each corresponding to one set of constants, as can be done with orthogonally arranged data,

as the effect of each constant of one set is confounded with a varying amount of the effects of the constants of the other set, which are themselves calculated with allowance for a varying amount of influence from those of the first set.

The resulting sum of squares between corrected means is the same as above if we write it in the more logical form

$$Sn'_p (Y_p - \overline{y}_t)^2$$

which $Sn'_p (Y_p^2 - 2Y_p \overline{y}_t + \overline{y}_t^2)$ $Sn'_p Y_p^2 - 2\overline{y}_t Sn_p Y_p + Sn'_p \overline{y}_t^2$

$$= Sn'_p Y_p^2 - 2\overline{y}_t S(y_t) + \overline{y}_t S(y_t) = Sn'_p Y_p^2 - \overline{y}_t S(y_t)$$

$$Sn_p Y_p^2 = S[Y_p S(Y_p)] \text{ over all cells}$$

$$\begin{aligned}
&= (m+a+j)\,n'_{11}(m+a+j) + (m+b+j)\,n'_{21}(m+b+j) \\
&+ (m+c+j)\,n'_{31}(m+c+j) + (m+a+u)\,n'_{12}(m+a+u) \\
&+ (m+b+u)\,n'_{22}(m+b+u) + (m+c+u)\,n'_{32}(m+c+u) \\
&+ (m+a+i)\,n'_{13}(m+a+i) + (m+b+i)\,n'_{23}(m+b+i) \\
&+ (m+c+i)\,n'_{33}(m+c+i) + (m+a+r)\,n'_{14}(m+a+r) \\
&+ (m+b+r)\,n'_{24}(m+b+r) + (m+c+r)\,n'_{34}(m+c+r)
\end{aligned}$$

If n'_{11} $(m + a + j)$ etc. are considered as single terms, and the factors of them taken singly from the first brackets, we find, for instance, that the factor a multiplies

$$n'_{11}(m+a+j) + n'_{12}(m+a+u) + n'_{13}(m+a+i) + n'_{14}(m+a+r)$$
$$= S(Y_a) = S(y_a)$$

the whole sum being equal to

$$mS(y_t) + aS(y_a) + bS(y_b) + cS(y_c) + jS(y_j) + uS(y_u) + iS(y_i) + rS(y_r)$$

as before; thus the sum of squares "removed by constants" may be called quite correctly the sum of squares "between corrected means". There are 10 corrected means, but to obtain them 5 independent constants were calculated from the data, and the general mean y or $\overline{y}_t$ absorbs one degree of freedom, leaving 4 degrees of freedom by which the above sum of squares must be divided to give the variance between corrected means.

Neue Konstantenbestimmungen des Meerwassers.

Von

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(I. Mitteilung).

In den Jahren 1899 bis 1901 sind in Kopenhagen auf Veranlassung der Internationalen Meeresforschung Konstantenbestimmungen des Meerwassers von einem Stabe von Gelehrten unter Leitung von M. Knudsen durchgeführt worden. Sie bezweckten eine Nachprüfung der bis dahin zur Reduktion hydrographischer Beobachtungen verwendeten Tafeln von Makaroff, Krümmel, Knudsen (»Ingolf«-Expedition) und anderen und sollten vor allem die Beziehung zwischen Chlorgehalt und Dichte des Meerwassers aufhellen. Die Ergebnisse dieser Untersuchungen bilden die Grundlage der hydrographischen Tafeln von Knudsen, die zur Charakterisierung der Dichte des Meerwassers den Chlorgehalt in die Ozeanographie eingeführt haben, da dieser Wert leichter mit genügender Exaktheit zu erhalten ist als ein Dichtewert. Diese Tafeln bilden auch die Grundlage für die Tabellen von Bjerknes, Hesselberg und Sverdrup, die für dynamische Berechnungen unentbehrlich sind.

Die grosse Bedeutung der hydrographischen Tabellen von Knudsen beruht darin, dass die Beobachtungstechnik ebenso wie die Verarbeitung des Materials hydrographischer Expeditionen durch ihre Verwendung wesentlich vereinheitlicht worden ist.

In den hydrographischen Tabellen ist der Dichtewert auf fünf, der σ-Wert auf zwei Dezimalstellen, der Chlorgehalt auf 1/100 ‰ genau angegeben. Man kann wohl ohne Übertreibung sagen, dass in dem Zeitraum seit Herstellung der Tafeln die Beobachtungsgenauigkeit von Temperatur und Chlorgehalt den zehnfachen Betrag derjenigen erreicht hat, welche sie um 1900 im Mittel wohl hatte. Infolge dessen treten Unterschiede zwischen direkt beobachteten Dichtewerten und nach den Tafeln aus dem Chlorgehalt berechneten in neuerer Zeit stärker in die Erscheinung, als es zur Zeit der Herstellung der Tafeln der Fall sein konnte. Die Verallgemeinerungen der Beziehung zwischen Dichte und Chlorgehalt und die Vernachlässigung ihrer Abhängigkeit von dem Verhältnis der Salzkomponenten war für die damalige Zeit völlig berechtigt. Heute aber können sie dazu führen, Feinheiten der Beobachtungen zu verwischen und vielleicht ein Verständnis der Dynamik des Meeres dann zu erschweren, wenn die Dichtedifferenzen der

Wassermassen in die Grössenordnung der Fehler fallen, die durch das Vernachlässigen der verschiedenen chemischen Zusammensetzung bedingt sind.

Es sind daher von zahlreichen Forschern gleichzeitige Beobachtungen von Chlorgehalt und Dichte angestellt worden, um die Grösse der Differenzen des beobachteten und berechneten Dichtewertes bei verschiedenartiger Zusammensetzung des Seewassers festzustellen. Von Nansen, Helland-Hansen und Sverdrup ist ein umfangreiches Material zu dieser Frage beigebracht worden.

Mit der Nachprüfung der Beziehung von Dichte und Chlorgehalt gehen des weiteren Versuche Hand in Hand, andere Eigenschaften des Meerwassers, als es Chlorgehalt und Dichte selbst sind, zur Charakterisierung der Dichte messend zu verwenden. Von den nordischen Ozeanographen und in neuerer Zeit von der Deutschen Seewarte ist die Salzgehaltsbestimmung durch optische Brechung und Interferenz mit dem Zeiss'schen Interferometer versuchsweise, jedoch mit geringem Erfolge, verwendet worden. Von den Amerikanern wird seit einer Reihe von Jahren die elektrische Leitfähigkeit zur Bestimmung des Salzgehaltes benutzt.

Das Institut für Meereskunde hat bereits 1925 ähnliche Untersuchungen geplant, sie wurden aber erst nach der Rückkehr der »Meteor«-Expedition zu einer Neubestimmung von Meerwasserkonstanten ausgestaltet und in Angriff genommen. Diese Arbeiten konnten dann in Zusammenarbeit von Physikalisch-Technischer Reichsanstalt und Institut für Meereskunde seit dem Jahre 1928 durchgeführt werden, da die Notgemeinschaft der Deutschen Wissenschaft sich dankenswerter Weise für diese Untersuchungen immer wieder einsetzte und die Direktoren der beiden Institute, Herr Professor Dr. A. Defant und Direktor Dr. Kösters diese Arbeiten in grosszügigster Weise förderten. Diese Zusammenarbeit hat sich im Laufe der 4 Jahre ausserordentlich günstig ausgewirkt, da die Physikalisch-Technische Reichsanstalt über die praktischen Erfahrungen mit physikalischen Messmethoden verfügte, die dem Institut für Meereskunde entsprechend der Problemstellung für die Neubestimmung der Meerwasserkonstanten notwendig waren.

Die Arbeiten bezweckten vor allem eine exakte Bestimmung der Dichte des Meerwassers und seines Ausdehnungskoeffizienten, die als Grundlagen aller weiteren Bestimmungen dienen sollten. Für die Festlegung der optischen Brechung des Meerwassers genügte das Zeiss'sche Interferometer nicht den Anforderungen, die an die Genauigkeit des Dichtewertes zu stellen sind, vor allem auch wegen des zu kleinen Dichtemessbereiches. Ein sehr exaktes Spektrometer und ein Hallwachs-Prisma wurden daher für die optischen Vorversuche angeschafft. Durch den Besuch der »Carnegie«-Expedition in Hamburg 1928 wurden wir angeregt, die Leitfähigkeit des Meerwassers noch als weitere Eigenschaft mit zu untersuchen. Zur Bestimmung wurde jedoch nicht der Saline-Taster des Bureau of Standards, Washington, verwendet, sondern eine besondere Versuchsanordnung zusammengestellt.

Die Methode der Bestimmung der Dichte ist seit etwa 50 Jahren von der Abteilung für Mass und Gewicht an der Physikalisch-Technischen Reichsanstalt ausgearbeitet und auf eine sehr hohe Stufe der Genauigkeit gebracht worden. Als Vorarbeit für die Leitfähigkeitsmessmethode lagen bereits ältere, grundlegende Untersuchungen von F. Kohlrausch vor, und für die Messung der optischen Brechung durch Interferenzen stand die langjährige Erfahrung der Abteilung für Längenmessungen zur Verfügung.

Unter der steten Anregung und tätigen Mitarbeit des Direktors der Abteilung für Mass und Gewicht an der Physikalisch-Technischen Reichsanstalt, Herrn Dr. Kösters, und seiner Mitarbeiter konnte die Methode zur Messung der optischen Brechung von Seewasser im Laufe von 3 Jahren zu ausserordentlich grosser Exaktheit durchgebildet werden. Ebenso wurde die Entwicklung der Methode zur Bestimmung der Leitfähigkeit des Seewassers von den Herren der Wechselstromabteilung der Physikalisch-Technischen Reichsanstalt in entgegenkommender Weise stets unterstützt. Auf Grund dieser langjährigen messtechnischen Erfahrungen der Reichsanstalt und der speziellen Vorarbeiten für die Methoden zur Bestimmung der Dichte, der optischen Brechung und der Leitfähigkeit des Seewassers sind seit 1928 derart bis in alle Einzelheiten entwickelt worden, dass die 6. Dezimale der Dichte stets als gesichert angesehen werden kann.

Um diese Untersuchungen mit den Werten, die auf Grund der Knudsen-Tafeln berechnet werden, in Beziehung zu setzen, wurde ausserdem die Chlortitration der Wasserproben als vierte Methode der Charakterisierung des Seewassers hinzugenommen. Für die Chlortitrationen konnte Herr Schindler vom Institut für Meereskunde freigemacht werden, der durch langjährige Übung eine so ausgezeichnete Technik der Titration entwickelt hat, dass er die 3. Dezimale des Chlorgehaltes in Promille richtig erhält.

Die Apparaturen, die für die 4 verschiedenen Bestimmungsmethoden verwendet worden sind, seien im folgenden kurz beschrieben:

1) Die hydrostatische Dichtebestimmung des Meerwassers.

Durch genaue Wägungen eines bekannten Glasvolumens, das in Luft, Wasser und Meerwasser gebracht wird, ist die auf Wasser als Einheit bezogene Meerwasserdichte messbar. Die hierfür benutzte Apparatur zeigt Fig. 1.

An der rechten Schale der empfindlichen 500 g Waage ist an einem dünnen Draht ein kleines Glasgehänge mit Haken befestigt. An den Haken kann der grosse Glasschwimmer *innerhalb* des mit Meerwasser gefüllten Standzylinders an- bezw. abgehängt werden. Ein Metalltrog umgibt den Standzylinder als Wärmeschutz. Die Gewichtsdifferenz (Gehänge + Schwimmer) — (Gehänge) wird mit Normalgewichten, deren Fehler genau bekannt sind, mehrmals gemessen. Dies geschieht unter ständiger Rührung des Meerwassers und Ablesung von 3 Thermometern, die in verschiedenen Flüssigkeitstiefen die Meerwassertemperatur angeben.

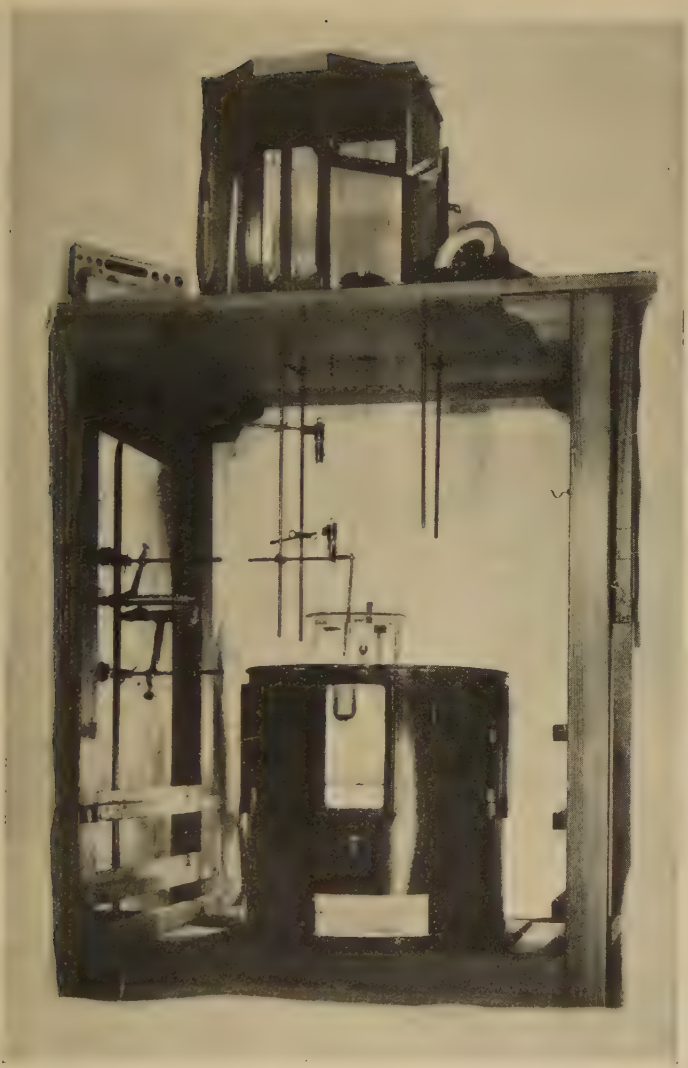

Fig. 1. Apparat für die Fundamental-Dichtebestimmung.

Eine Hauptfehlerquelle der Methode bildet der durch die Wasseroberfläche gehende Aufhängedraht. Zur Verminderung der Kapillarkräfte wird nach Kohlrausch platinierter Platindraht benutzt, dessen Aufhängeschlingen über oder unter der Wasseroberfläche liegen. Durch Aufbringen eines winzigen Tropfens von Oleinsäure auf den Flüssigkeitsspiegel wird eine gute Benetzung am Draht erreicht. Schliesslich ist die Meerwasseroberfläche mit einer 2 mm dicken Paraffinölschicht bedeckt, um Konzentrationsänderungen durch Verdunstung zu verhindern.

Die nach diesen Vorsichtsmassregeln erreichte Genauigkeit beträgt 1/1000000 des Schwimmergewichts (ca. 100 g) bzw. der Dichte, wenn die Temperatur auf 1/100° genau bekannt ist. Die nachfolgende Messreihe gibt hierfür ein Beispiel.

Tab. 1.

Beobachtungs-Datum:	Zeit:	Temperatur:	Schwimmergewicht im Meerwasser
10.6.32	13h 40m	17°44 C	94956,77 mg
	50m	44½	94956,97 »
	58m	17°45	94957,32 »
11.6.32	10h 28m	17°43	94956,85 »
	35m	43	94957,06 »
	42m	43	94957,03 »
		Mittel	94957,00 ± 0,09 mg.

2) Die optische Bestimmung der Meerwasserdichte.

Die einfache Abhängigkeit des optischen Brechungsexponenten einer Flüssigkeit von ihrer Dichte ermöglicht es, die Meerwasserdichte durch Beobachtungen der optischen Brechung zu messen. Zur Erzielung höchster Genauigkeit wird die Brechungsdifferenz zwischen Meerwasser und destilliertem Wasser mit einem neuartigen Interferometer bestimmt.

Das vom Kollimator gesammelte weisse Licht einer Lampe wird durch ein ausserordentlich wirksames Kösters'sches Doppelprisma in 2 kohärente Strahlenbündel zerlegt, die nach der Reflexion an einem Spiegel interferieren. Im Gesichtsfeld des Fernrohrs ist dann ein sehr lichtstarkes Interferenzbild sichtbar, das aus einem schwarzen und mehreren dazu symmetrisch angeordneten farbigen Streifen besteht. Wird in die beiden Strahlenbündel eine Doppelkammer gebracht, deren linke Hälfte destilliertes Wasser, deren rechte Meerwasser enthält, so entsteht ein der Brechungs- oder Dichtedifferenz äquivalenter optischer Gangunterschied. Die dadurch in der oberen Gesichtsfeldhälfte bedingte Verschiebung des Interferenzsystems wird achromatisch kompensiert durch die Dickenänderung eines Glaskeils. Der Dispersionsverlauf des Keils ist der Dispersionsdifferenz von Meerwasser und destilliertem Wasser angepasst. Die Keil-Nullstellung entspricht dem in der unteren Gesichtsfeldhälfte dargestellen Gangunterschied Wasser — Wasser = 0 und wird bei der Übereinstimmung der Keildicke mit der Dicke einer Glasplatte erreicht. Die von diesem Nullpunkt gezählte Keilverschiebung, die mittels einer Mikrometerschraube erfolgt, ist das Mass der Brechungsdifferenz oder nach empirischer Eichung des Dichteunterschieds von Meerwasser und destilliertem Wasser.

Die Genauigkeit der Einstellung, bei der die schwarzen Streifen oben und unten im Gesichtsfeld zur Deckung zu bringen sind, beträgt

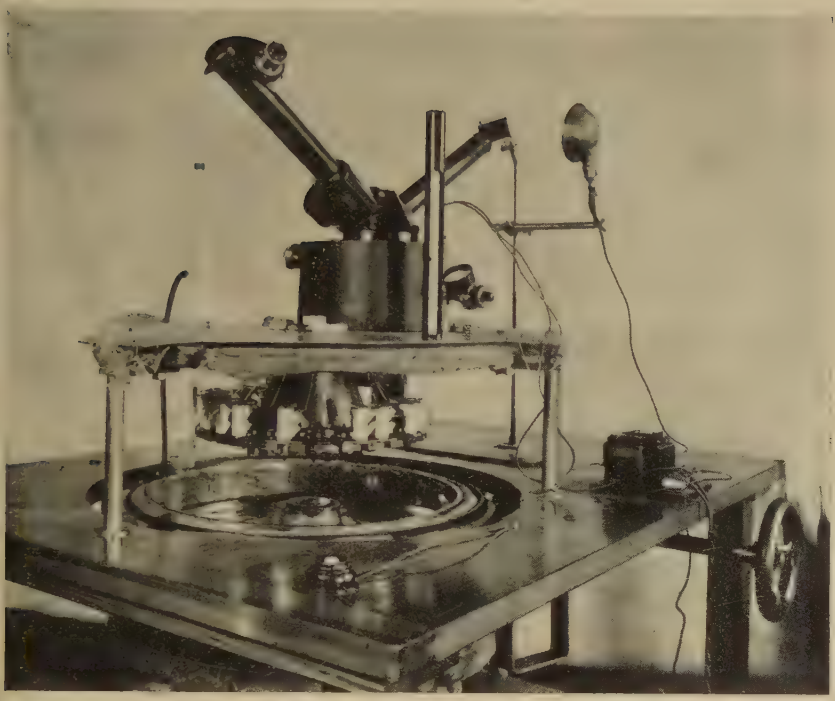

Fig. 2. Das Askania-Interferometer.

$^1/_{10000}$ des Brechungsunterschieds, wodurch die 6. Dezimale der Dichte sicher messbar ist.

Das von den Askania-Werken, Berlin-Friedenau, nach diesem Prinzip von Direktor Dr. Kösters erbaute Instrument zeigt Fig. 2. Ausser der justierbaren optischen Ausrüstung sind zur Erleichterung der Messungen verschiedene Einrichtungen getroffen. So sind zur Unterteilung des Keilmessbereichs statt einer einzigen Platte 5 Glasplatten gegeneinander auswechselbar, deren Dicken bei der Keilnullstellung einem Salzgehalt des Meerwassers von ca. 0, 10, 20, 30, 40 ‰ entsprechen. Ferner können innerhalb des mit destilliertem Wasser gefüllten Troges mittels einer Drehscheibe 26 Kammern wahlweise temperiert, in den optischen Strahlengang gebracht und gemessen werden. Jede dieser Meerwasserkammern besteht aus einem im Profil rechteckigen, 4 cm langen und mit verschliessbaren Füllöffnungen versehenen Porzellanrohr, das oben und unten mit je einer überragenden optischen Plan-Glasplatte verkittet ist. Die überragenden Glasplattenteile ersetzen die oben erwähnte linke Kammerhälfte, indem das destillierte Temperierwasser des Troges als Vergleichswasser dient.

In Tab. 2 ist eine Messreihe dargestellt, die trotz der verschiedensten Beobachtungstemperaturen die Genauigkeit der Interferenzmethode erkennen lässt.

Tab. 2.
Temperatur-Reduktionstafel für die Interferometer-Ablesungen im Intervall von 12° bis 26° C.

Tab. a.					Tab. b. Meerwasserlösung $\rho = 28{,}00$				
	Reduktion	Beobachtungs-			Red.	Wert	Red.	Red-Wert	
t°	a	Datum	Uhr	Temp.	a	A_t	a 10^{-5} A_t	A_{20^0}	Abw.
12	—2234	26.7.	11h	21,96	+ 448	67405	+ 302	67707	+ 2
5	2073		1	22,02	+ 461	7391	+ 311	702	— 3
13	1915	27.7.		22,22	+ 505	7368	+ 340	708	+ 3
5	1760	28.7.	10	21,22	+ 283	7514	+ 187	701	— 4
14	1608		11	21,19	+ 276	7515	+ 186	701	— 4
5	1459	29.7.		20,49	+ 116	7628	+ 78	706	+ 1
15	1313	30.7.		20,59	+ 139	7614	+ 94	708	+ 3
5	1169	22.8.		24,52	+ 984	7037	+ 660	697	— 8
16	1029	24.8.		23,50	+ 776	7174	+ 521	695	—10
5	891	25.8.		22,75	+ 619	7289	+ 416	705	0
17	756	27.8.		22,35	+ 533	7354	+ 359	713	+ 8
5	624	29.8.		22,12	+ 483	7380	+ 325	705	0
18	494	30.8.		22,82	+ 634	7274	+ 426	700	— 5
5	366	31.8.	11	22,66	+ 600	7297	+ 404	701	— 4
19	242	31.8.	2	22,69	+ 606	7291	+ 408	699	— 6
5	— 120	1.9.		21,88	+ 430	7421	+ 290	711	+ 6
20	0	2.9.		19,38	— 149	7811	— 101	710	+ 5
5	+ 118	5.9.		18,35	— 404	7984	— 275	709	+ 4
21	233	12.9.		20,27	+ 64	7663	+ 43	706	+ 1
5	346	13.9.	10	18,29	— 420	7987	— 286	701	— 4
22	457	13.9.	12	18,05	— 481	8034	— 327	707	+ 2
5	566	14.9.		16,30	— 946	8349	— 647	702	— 3
23	672	15.9.		16,27	— 954	8359	— 652	707	+ 2
5	776	21.9.		15,69	—1116	8465	— 764	701	— 4
24	879	22.9.		13,54	—1748	8913	—1205	708	+ 3
5	980	29.9.		14,61	—1427	8688	— 980	708	+ 3
25	1078	4.10.		12,67	—2019	9106	—1395	711	+ 6
5	1174	6.10.		12,21	—2165	9210	—1498	712	+ 7
26	+1269	7.10.		12,06	—2215	69239	—1534	67705	0
						Mittel		67705	± 4

Die mittleren Abweichungen sind von der Grösse der Beobachtungsfehler.

Zur Reduktion der Interferometerablesungen A_t für Wasser mit ρ 17,5 = 28.008 auf die Normaltemperaturen von 20° C. sind die Messwerte mit dem Faktor $1 + a \cdot 10^{-5}$ zu multiplizieren, wobei a mit dem richtigen Vorzeichen aus Tabelle a durch Interpolation (bis auf $^1/_{100}$° C. genau) zu entnehmen ist. Tabelle b zeigt ein Beispiel, in dem die Beobachtungswerte bereits vorher auf denselben Nullpunkt, Normalwasserwert und Streifenwert korrigiert sind.

3) Die elektrische Dichtebestimmung des Meerwassers.

Die Dichte des Meerwassers wird nach dieser Leitfähigkeits-Methode durch den Ohmschen Widerstandswert eines bekannten Meerwasservolumens gemessen.

Diese Messung geschieht in der bekannten Wechselstrom-Brückenschaltung. Durch Abgleichen des veränderlichen Widerstands R_v und

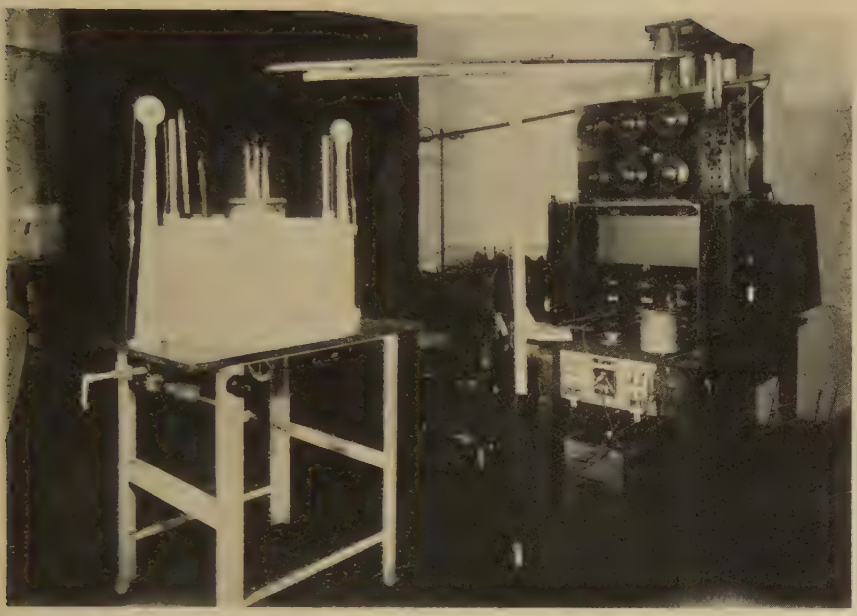

Fig. 3. Apparatur zur Bestimmung der elektrischen Leitfähigkeit.

der Kapazität C_v wird das Telefon nur dann stromlos, wenn der Widerstand X der mit Meerwasser gefüllten Zelle gleich $\frac{R_2}{R_1} \cdot R_v$ ist und in den Abzweigpunkten A und D Phasengleichheit besteht.

Die Schärfe des Tonminimums im Telefon hängt von der Frequenzreinheit der Wechselstromquelle und der Präzision der Widerstände R_1, R_2 und R_v ab. Die letzteren sind Wolf'sche Präzisionswiderstände und daher praktisch induktions- und kapazitätsfrei. Als Wechselstrom-Generator dient ein Spezial-Röhrensender nach Prof. Scheringe, Göttingen.

Durch Koppelung werden wahlweise die Frequenzen 800 oder 1200 Hertz auf die Brücke übertragen. Der sehr schwache Brückenstrom, der die Messzelle nicht nachweisbar erwärmt, wird durch eine abgeschirmte Dreifachröhre von Loewe verstärkt und mit einem geerdeten Ringübertrager, der freundlicher Weise von dem Carlswerk von Felten und Guillaume, Köln, zur Verfügung gestellt wurde, in das Telefon oder Vibrationsgalvanometer (nach Dr. Schmidt, Phys.-Techn. Reichsanstalt) geleitet.

Ausser dem Brückenpunkte C sind alle negativen Batteriepole und Abschirmungen geerdet. Die Einstellung ist dadurch weitgehend störungsfrei, die Genauigkeit beträgt $^1/_{10000}$ des Widerstandes.

Die Messzellen haben infolge der günstigen Wahl der Ringelektroden und Zuführungen sehr geringe Eigenkapazität und Selbstinduktion. Sie befinden sich nach Fig. 3, die den Gesamtaufbau der Apparatur wiedergibt, in einem grossen Temperierbad mit Rührwerk, da diese Methode ganz besonders temperaturempfindlich ist.

Das nachfolgende Messbeispiel zeigt bei konstanter Beobachtungstemperatur die Genauigkeit und die geringe Abhängigkeit der Einstellungen von der Senderfrequenz.

Tab. 3.

Zelle:	R_2/R_1	800 Hertz R_v	800 Hertz C_v	1200 Hertz R_v	1200 Hertz C_v	800 Hertz R_v	800 Hertz C_v
1	1000/1000	1273,5 Ω	40°	1273,2 Ω	33°	1273,5 Ω	41°
	500/500	6½	50°	3	44°	6	51°
	1500/1500	6	56°	3	48°	6	54°
2	1000/1000	1708,4	37°	1708,0	36°	1708,4	38°
	500/500	5	44°	1	44°	5	45°
	1500/1500	5	49°	1	46°	5	50°
3	1000/1000	1104,3	27°	1104,05	26°	1104,3	29°
	500/500	4	40°	2	38°	4	41°
	1500/1500	4	46°	1	43°	4	45°
	Temperatur	20°60 C		20°60 C		20°60 C	

4) Die Chlortitration der Meerwasserproben.

Der Chlorgehalt des Meerwassers wurde nach der Mohr'schen Methode bestimmt. Verwendet wurden Standbüretten, die in Zusammenarbeit mit der Physikalisch-Technischen Reichsanstalt und der Firma Richter & Wiese allmählich entwickelt worden sind. Um das Gesamtintervall von 0 bis 40 ‰ zu erhalten, wurde ein Satz von Büretten hergestellt, welche die Intervalle von 0 bis 5, 5 bis 10, 10 bis 15, 15 bis 20, 20 bis 25 ‰ umfassten. Wie Fig. 4 zeigt, sind in den Büretten niederer Konzentrationen unterhalb der Teilung besondere Kugeln eingeschmolzen, die eine Bestimmung des Normalwassers mit derselben Bürette, mit der die Proben titriert wurden, durch einmaliges Ablaufen ermöglichen.

Die Bürettenrohre haben einen Querschnitt von ¼ q.cm, sie sind im Mittel 60 cm lang und in 1/100 Doppelkubikzentimeter eingeteilt. Die Korrekturen für die Kaliberfehler wurden für die Temperatur von 17,5° in der Physikalisch-Technischen Reichsanstalt ausserordentlich genau auf Kubikmillimeter bestimmt. Die Prüfung wurde in Intervallen von 1 c.cm vorgenommen, sodass auf die Skala bis zu 13 Kontrollwerte kommen.

Das Wasser für die Titration der Proben ebenso wie für alle anderen Bestimmungen wurde stets nach der Fundamentalbestimmung der Dichte aus dem 9 Liter fassenden Dichteapparat direkt entnommen, um die Vergleichbarkeit der Wasserproben gewährleisten zu können, und dann wurde mit einer 15 c.cm. automatischen Pipette die Seewasserprobe abgemessen. Die Titrationen wurden ausserordentlich gleichmässig durchgeführt. Im allgemeinen wurden 15 Titrationen von jeder Probe und 6 Normalwasserbestimmungen gemacht. Als Beispiel für die durch die Titration erreichte Genauigkeit seien folgende Werte angegeben:

Fig. 4. Bürettensatz für die Bestimmung des Chlorgehaltes durch Titration.

Tab. 4.

Bürette Nr.	Pipette Nr.	Lab. Temp.	Probe	Ablesung	Büretten Korrektur	α	k	Cl
267	62	20.2	NW	19,410	— 0.017	— 0.014		19.379
			NW	19.410	— 0.017			19.379
			Probe	15.886	— 0.011		+ 0.062	15.937
			„	7	— 0.011			8
			„	8	— 11			9
			„	8	— 11			9
			„	7	— 11			8
			„	6	— 11			7
			„	7	— 11			8
			„	8	— 11			9
			„	8	— 11			9
			„	8	— 11			9
			NW	19.409	— 0.017	— 0.014		19.379
			„	10	— 17			19.379
			„	10	— 17			19.379

Mit diesen vier Methoden konnten eine grosse Reihe von Meerwasserproben bearbeitet werden, die dankenswerter Weise vom Vermessungsschiff »Meteor« und den Kommandos der Kreuzer »Emden«, »Karlsruhe« und »Köln« durch Vermittlung der Nautischen Abteilung der Marineleitung dem Institut für Meereskunde aus den verschiedensten Meeresgebieten beschafft werden konnten.

Durch diese Beobachtungen konnte eine erste vergleichende Übersicht über Dichte, optische Brechung und Leitfähigkeit des Meerwassers in ihrer Abhängigkeit von Temperatur und Konzentration gewonnen und diese in Beziehung zu einander und zu den durch die Knudsen'schen Tafeln aus den Chlortitrationen für dieselben Proben erhaltenen Werte gesetzt werden.

Eine kurze Zusammenfassung der bisher erhaltenen Ergebnisse und der Plan für weitere Untersuchungen von Meerwasser aus allen Teilen der Ozeane soll in einer zweiten Mitteilung gegeben werden. Die ausführliche Darstellung der Untersuchungen wird in den Wissenschaftlichen Ergebnissen der Deutschen Atlantischen Expedition Band VII, 2, im Laufe dieses Jahres erscheinen.

Summary.

Determination of the Chlorinity was introduced into Oceanography by M. Knudsen in order to describe the density of sea water. Knudsen's Hydrographic Tables have been useful in rendering the observations made on the numerous expeditions since 1902 more or less uniform. Nevertheless, a difference exists between the values of density obtained by direct measurement and by Knudsen's Tables. The Physikalisch-Technische Reichsanstalt and the Institut für Meereskunde have, therefore, recently undertaken the determination of density, by direct weighing, and thermal expansion of many samples of sea water. They have further attempted to determine the density by measuring the optical refraction and the electrical conductivity. The observations made in this way are of great precision (10^{-6} in density). The densities of a great number of sea water samples from very different parts of the ocean have been determined directly, as well as by measuring the optical refraction and electrical conductivity, and by titrating the chlorine. These results enable comparisons to be made between the different values found for any particular sample, and in addition they show the extent to which these values are functions of temperature and concentration of the sample.

The full description of the investigations and results will be published in 1933 in: Wissenschaftl. Ergebnisse der Deutschen Atlantischen Expedition auf »Meteor«, Bd. VII, 2.

An Examination of "Eau de Mer normale P 13, 28-VI-1929".

By

G. E. R. Deacon, B. Sc.,
Hydrologist, R. R. S. "Discovery II",

with an Appendix by

D. J. Matthews,
Hydrographic Dept., Admiralty, London.

(Introductory Note. The author omitted to give the atomic weights which he used, and to say whether or not he applied any correction to the weight of the sodium chloride for the buoyancy of the air. Since it would have caused great delay to return the paper to him in the Antarctic for amendment, a telegram was sent asking for the missing information, and the following reply was received:— "Weight of sodium chloride in vacuum 16.4005 grammes, correction plus 0.5 milligrammes. Atomic weight 1925, sodium 23.00, chlorine 35.46". The paper has been printed as received, and the necessary slight modifications are made by Mr. Matthews in the appendix, which has been added in this country, and for which the author is not responsible in any way. *Editor).*

We were informed in a recent communication from England that some doubts had been expressed as to the reliability of standard sea water. Since we are entirely dependent in the R. R. S. "Discovery II" on this water we have at the first opportunity examined our own stock. In the following there is a brief account of previous work on the validity of standard sea water to which we have access, and of our own experience in its use.

The use of standard sea water has been criticized by Bertrand, Freundler and Mlle. Ménager (1922) and by Mlle. Ménager (1924). They do not question its chlorine content but rather the chlorine-density ratio in different waters. In both papers the use of pure sodium chloride solutions is recommended, and also that titrations should be referred to volumes instead of weights. The water itself was condemned by Giral (1926) who states that, however carefully standard sea water is made in the first instance, it dissolves so much chlorine from the glass container that, after a time, its chlorine content is raised by 0.15 ‰. This has been shown by Matthews

(1926) to be impossible. Professor Giral also attacks the mode of titration normally used in a way which seems quite unwarranted. A sample examined by Thompson (1928) who compared standard sea water with a pure sodium chloride solution was found to have exactly the chlorine content specified.

Since leaving London in October 1931 we have opened and used 48 tubes of standard water. It has been our practice to compare a newly opened tube with the last opened, and, at the same time, to compare the titrations made on the very deep water at each station with those of the preceding stations, so that any unusual variation could be examined. It is very probable that a variation of $\pm$ 0.01 $^0/_{00}$ of chlorine in the standard water would have been noticed. An unusual change in the titration of the silver nitrate solution, which is used every morning when the ship is at sea, would also have excited suspicion.

Only one tube was found to be faulty and this had a very clumsy seal at one end. The chlorine content of the water in this tube was, however, only 0.015 $^0/_{00}$ too high.

To make quite sure that our remaining stock of 65 tubes was above suspicion 8 tubes have been compared with 3 pure sodium chloride solutions of the same chlorine content.

Preparation of Pure Salt.

The B. D. H. analytical reagent was dissolved in distilled water until a saturated solution was obtained. This solution was filtered and precipitated with hydrogen chloride. The liquid was poured off and the salt washed with A. R. hydrochloric acid and dried for 12 hours at 340° C. The salt was redissolved and precipitated with redistilled absolute alcohol and dried for 24 hours at 150° C. in an electric oven. It is believed that the only impurity then present was a minute trace of alkali (Andrews & Worley, 1927). Two samples of the pure salt were made in this way, and in the preparation of a third the redissolving and precipitation with alcohol was repeated 3 times.

It was then necessary to use the salt to make up sodium chloride solutions which had the same chlorine content per litre as the standard sea water, and then to make a direct comparison of the volumes of the same silver nitrate solution used in titrating the two sets of solutions. The solutions were made up and the titrations carried out at a temperature of 15° C. The standard sea water was supposed to contain 19.384 $^0/_{00}$ and the density of this water at 15° C. was found from tables (Knudsen, 1901) to be 1.02601. Standard sea water therefore contains 19.8882 g. Cl in 1 litre at 15° C. and a salt solution containing the same concentration of chlorine, 16.3940 g. NaCl in 500 ccm.

16.3940 g. were weighed from each of the 3 samples of pure salt, dissolved in distilled water free from chloride, and made up to 499.95

ccm., the volume of the flask used at 15° C. The solutions were then preserved in carefully cleaned, washed, stoppered bottles.

Two tubes of standard sea-water were taken from 15 tubes remaining in the box of 50 in use, and six from all parts of a new box. These were opened and preserved in the same way.

The eleven bottles were placed together and the temperature of the laboratory kept at 15° C. for 24 hours during which time the large reservoir of 20 litres of silver nitrate solution was mechanically stirred.

The titrations were then made using a Knudsen burette and pipette, the precipitate being ground finely in a large white evaporating dish.

The following table shows the results obtained.

Solution	Burette readings[1]) 1st titration	2nd titration	3rd titration
Standard sea water from old case.			
1	19.395	19.390	19.395
2	19.395	19.390	19.390
Standard sea water from new case.			
1	19.395	19.395	
2	19.390	19.390	
3	19.390	19.395	19.395
4	19.395	19.390	19.390
5	19.390	19.390	
6	19.390	19.390	
Pure NaCl solutions			
1	19.390	19.390	
2	19.395	19.390	19.395
3[1])	19.390	19.395	19.390

[1]) (Salt precipitated 3 times with alcohol).

The agreement between all the titrations was found to be most remarkably good, and to fall well within the limits of experimental error.

The average of the 20 titrations of standard sea water is 19.392, and that of 8 titrations of pure sodium chloride solutions also 19.392. Allowing for the 0.05 error in the 500 cc. flask and supposing the NaCl solutions perfect the chlorine content of the standard sea water is therefore 19.386 ‰.

Summary.

Constant use of the standard sea water supplied by the Laboratoire Hydrographique, and labelled "Eau de Mer Normale P. 13, $^{28}/_{6}$, 1929",

[1]) To obtain the actual volume of silver nitrate solution used at 17.5° C., the temperature at which the burette was calibrated, the burette reading must be multiplied by 2 (1 + 0.0010).

gave every indication that the water did not vary in strength beyond the limits of experimental error.

Actual comparison with pure sodium chloride solutions shows that this is definitely so, and that the chlorine content 19.384 ‰, is correct to the nearest 0.005 ‰, which is the limit of possible accuracy for an ordinary worker.

I desire to express my indebtedness to Professor F. P. Worley, Auckland University College, University of New Zealand, for his advice, and for providing me with facilities for making accurate solutions, without which the work could not have been done.

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Appendix.

The Chlorine of every batch of Normal Water[1]) is referred ultimately to the chlorine contained in a sample of potassium chloride which was prepared by S. P. L. Sørensen[2]) in connection with the computation of Knudsen's Hydrographical Tables 1901. He weighed some of this, made the correction to vacuum, and used it for the titrimetric standardisation of a solution of silver nitrate. This solution was used in its turn for the titration of the chlorine in the sea water which was the ultimate standard to which the normal waters are referred. The chlorine content of a normal water therefore depends upon the atomic weights which Sørensen used.

It is obvious that Mr. Deacon's results should be calculated with the same atomic weights as were used by Sørensen, but this is not possible since he used sodium chloride instead of potassium chloride. It is not sufficient to use the atomic weight for sodium which Sørensen quotes in connection with another part of the investigation, since this would be making the inadmissible assumption that the ratio of the two atomic weights was known accurately; it is equally inadmissible to assume that the atomic weights for the

[1]) L'Emploi de l'Eau normale dans l'Océanographie. Martin Knudsen. Cons. Perm. Int. pour l'Explor. de la Mer. Pub. de Circ. No. 87. Copenhagen 1925.

[2]) Ber. über die Konstantenbestimmungen zur Aufstellung der Hydrographischen Tabellen von Carl Forch, Martin Knudsen und S. P. L. Sørensen. D. Kgl. Danske Vidensk. Selsk. Skr. 6. Række, Naturv. og mathem. Afd. XII. 1. København 1902.

year 1932 are known with accuracy, for they will almost certainly be changed at some future time.

Mr. Deacon's results have therefore been recalculated, making the correction of the weight of the sodium chloride to vacuum, and using the constants given in Tables 1 and 2 below. Table 3 has been added as a matter of interest; it shows the change in the accepted value of the ratio Na : K.

Table 1. Atomic Weights.

Year	Cl	Na	K
1902	35.453	23.058	39.136
1925	35.457	22.997	39.096
1932	35.457	22.997	39.10

Table 2. Percentage of Cl in NaCl, according to the atomic weights in Table 1.

Year	1902	1925	1932
Percentage	60.592	60.658	60.658

Table 3. Ratio of Na:K.

Year	1902	1925	1932
Ratio	0.58918	0.58822	0.58816

We have then

Weight of sodium chloride taken, in air ..	16.3940 grammes
Correction for buoyancy of the air	0.0065 grammes
Weight of sodium chloride in vacuo	16.4005 grammes

The sodium chloride was dissolved in water and made up to 499.95 ccm. Then the chlorine content per 1000 ccm. is, using the percentages given in Table 2

Year	1902	1925	1932
Chlorine	19.877	19.898	19.898

The mean of the titrations shows that the normal water under examination had exactly the same chlorine content as the solutions of sodium chloride, and we therefore arrive at the following results:—

Nominal chlorine per 1000	19.384
Calculated from atomic weights of year 1902	19.373
» 1925	19.394
» 1932	19.394

The figures are sufficient to show that there was no error in the nominal chlorine of the normal water as great as had been alleged, and it is virtually certain that there was no error of importance to oceanography.

Donald J. Matthews.
14. Oct. 1932.

Results obtained with a Thermograph for Surface Temperatures during the „Snellius" Expedition.

By

H. C. Hamaker.

Mainly with a view to replacing the bucket observations of sea surface temperatures by a more reliable and continuous record, the performance of various types of thermographs has been investigated in recent years. The apparatus used on board H. M. S. »Snellius« during the expedition in the East Indian Archipelago differed in certain principal points from other types hitherto described. Since the results have been satisfactory and may therefore be of some use to others, a description of the instrument is given below.

The instrument consisted of an electrical resistance, the variations of which with temperature were recorded by a galvanometer of special construction. The resistance was formed of iron wire and had a value of about 200 ohm. A variation of 1°C. in temperature corresponded to a variation of very nearly 1 ohm in the resistance. Since the resistance of the conducting wires leading from the thermometer to the galvanometer was only about 0.5 ohm variations in the temperature of the leads did not appreciably influence the accuracy of the records.

The resistance was protected by a sheath of Krupp V2A steel and fitted in a cubical recess specially made for the purpose in the ship's side. A plan of the construction is given in figure 1. The screen A was made in such a way as to ensure a better circulation of the sea water when the ship was moving.

Full details of the construction cannot be given here. It may be said, however, that the resistance thermometer functioned consistently well during the whole expedition. No trouble was experienced from corrosion of the material.

The cubical recess with the resistance thermometer was placed on the starboard side about 15 metres from the bow, 1.2 metres below the water-line.

As has already been mentioned the galvanometer used was of a rather special construction.

In a magnetic field two crossed coils C_1 and C_2 move together. These two coils form part of two different circuits coupled in parallel on the same battery B. One circuit contains the coil C_1 and the thermometric resistance Th; the other circuit contains the coil C_2 and a constant resistance R of manganin wire. There is no resultant torque acting on the coils. The position of the two coils in the magnetic

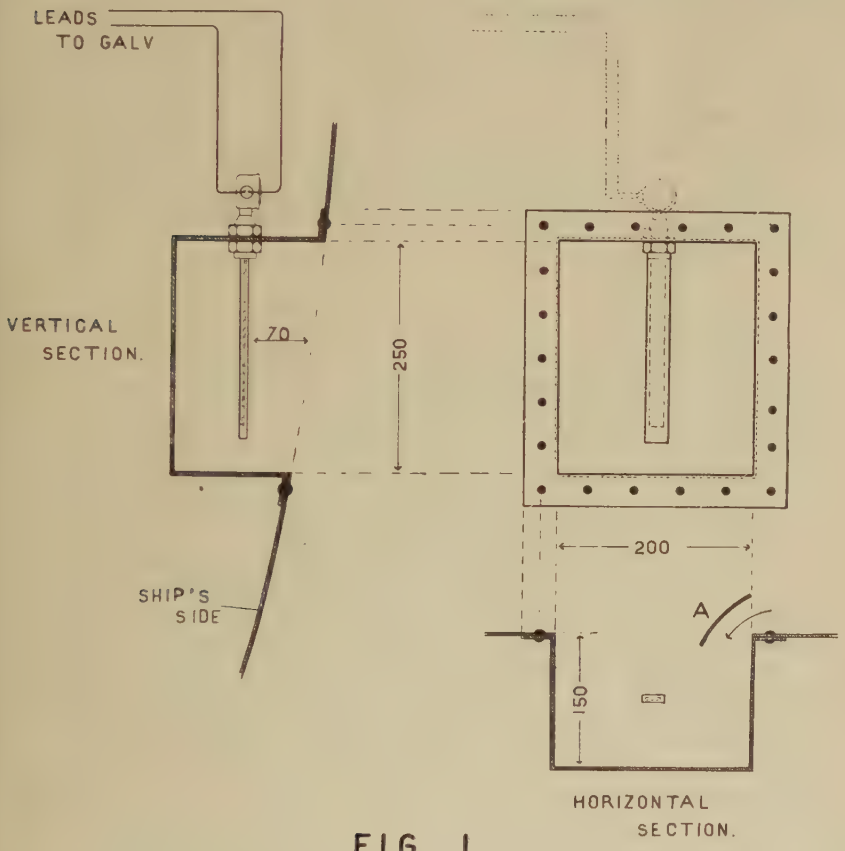

FIG. 1.

field will be such that the couple acting on C_1 balances the couple acting on C_2. But, since both couples increase or decrease in the same ratio, as the voltage of the battery increases or decreases, the readings of the instrument will be independent of variations in the voltage of the battery. This is of very great advantage, since it renders a regular check of the battery voltage superfluous.

Of course, the voltage should not vary between too wide limits, but with the instrument used on board H. M. S. »Snellius« variations of as much as 0.5 volts did not cause any appreciable error in the records.

The battery consisted of six dry elements, coupled 2 in parallel and 3 in series. Once every two months the elements were renewed.

The construction of the instrument is such that the deflection of the needle varies almost linearly with the temperature of the sea water. Moreover, the needle moves freely. It is pressed by clockwork once a minute against the registration paper, which runs at a speed of 2 cm. per hour.

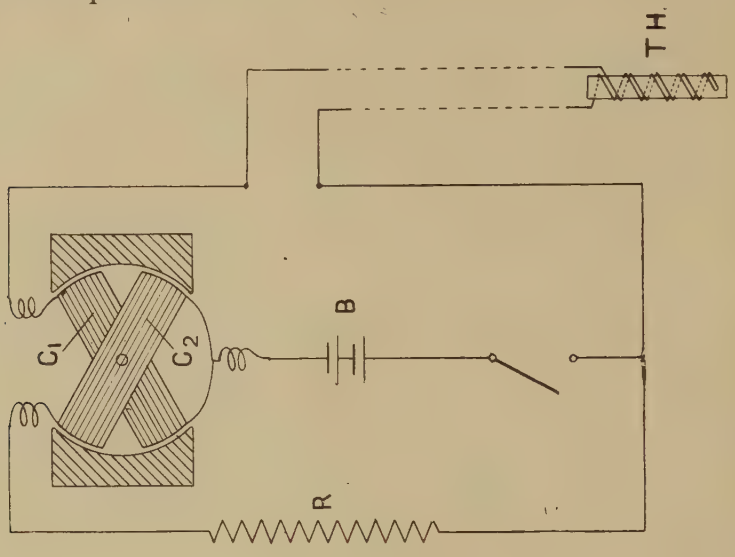

Fig. 2.

The apparatus was manufactured by the well-known firm of Hartmann and Braun and was found to be excellent. Perhaps it is worth mentioning that there exists a similar instrument capable of recording the temperatures of 6 different places in different colours on the same strip of paper.

At the very outset the thermograph did not function particularly well. The galvanometer was fixed rigidly to the body of the ship and it appeared that the motion of the ship due to waves caused irregularities of about 0.5° C. in the records. Later on the galvanometer was suspended in such a way that it could swing freely in all directions, thereby greatly improving the registration. Even in fairly rough weather the temperatures were recorded in a smooth trace, as may be seen from figure 3a, a reproduction of the record on the 26th of September, 1930.

That day at 8 o'clock in the morning the anchor was weighed in the strait of Lembeh on the NE. coast of the Minahassa. Coming out of the strait into the open sea a rise of temperature of 2° C. was observed. The strait of Lembeh lies between a little island and the NE. coast of the Celebes. In the strait strong currents were observed and many eddies could be seen at the surface. The low

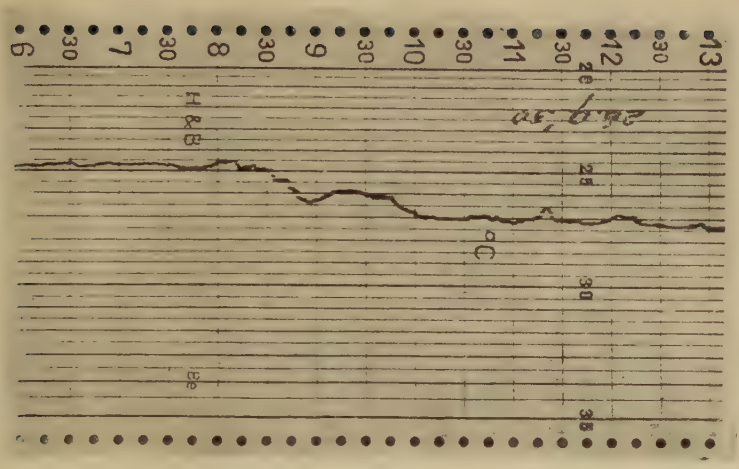

Fig. 3 a.

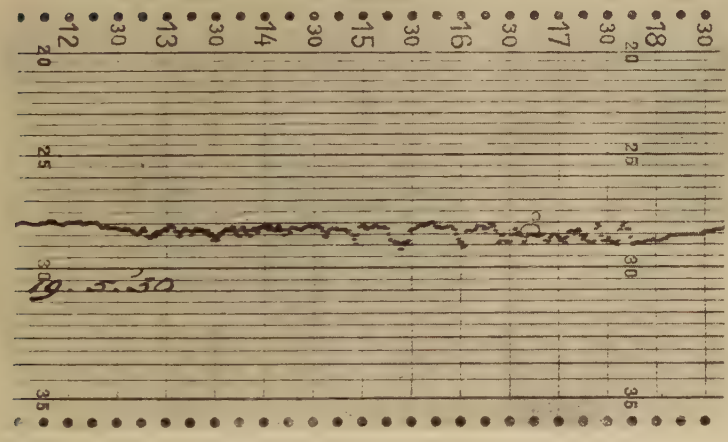

Fig. 3 b.

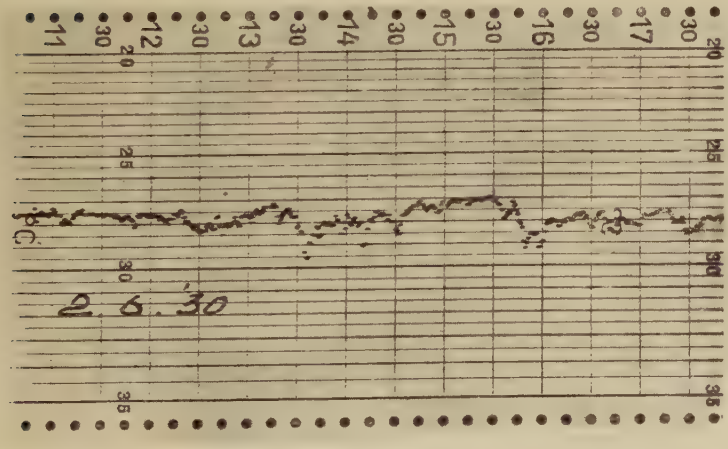

Fig. 3 c.

temperature inside the strait can therefore be readily explained by the mixing of the surface water with cold water from deeper layers.

Outside the strait rather rough weather was encountered; from 11 o'clock onwards the wind velocity varied between 10 and 12 metres per second, giving rise to a heavy swell. It may be seen from the reproduction in figure 3a that in spite of the change in weather conditions the temperature record does not show any change in character; the trace is just as smooth in rough as it is in calm weather.

During the first months of the expedition the only check on the records was bucket observations made by the Officers every two hours. In addition to these, systematic control measurements with a reversing thermometer, let down in the near neighbourhood of the resistance thermometer, were started in December 1929 and continued until the end of the expedition. The frequency of occurrence of various differences between the temperatures thus observed and those from the records is given in table 1.

Table 1.

Frequency of differences between recorded temperatures and temperatures observed with reversing thermometer.

Diff. in °C.	Frequency	March '30.	Diff. in °C.	Frequency	March '30.
1.0	3		1.5	4	4
1.05	1		1.55	0	3
1.1	2		1.6	1	7
1.15	7		1.65	0	6
1.2	21		1.7	0	6
1.25	13		Abnormal values		
1.3	19		0.05	1	
1.35	12		0.7	1	
1.4	3		0.75	1	
1.45	0	1	0.8	1	

It is seen from this table that a constant difference exists between observed and recorded temperatures, the thermograph reading 1.25° C. too low. This difference could easily have been corrected by adding a constant resistance of about 1.2 ohm to the resistance of the thermometer and leads. In fact, this would have been the right way to adjust the instrument after it had been installed. A small coil of manganin wire was supplied with the apparatus for this purpose. Since this coil was lost and insufficient wire was at hand to replace it, the adjustment could not be correctly made. Hence the constant difference resulted.

Furthermore, in table 1, an exception has been made for the month of March 1930. During this month a constant deviation of 1.6° C, was found instead of 1.25° C., the normal value. This increase of the correction was found to be due to an exceptionally low voltage

of the battery, which during March 1930 was about 3 volts instead of the usual 4½ v.

After applying a constant correction of 1.25° C. (1.6° C. in March '30) to the recorded temperatures the agreement with the observed values is very good. The remaining differences have a root mean square value of only 0.1° C. This should be practically the mean error of the thermograph, if the errors of the reversing thermometer observations are small compared with the errors of the temperature records. At least we may say that the thermograph gives the temperature of the water layer 1.2 metres below the surface with a mean error which does not exceed 0.1° C., an accuracy satisfactory for the purpose.

If we next compare the corrected temperature records with the bucket observations made on the bridge, an average difference of 0.3° C. is found, the bridge observations being too low. The greater part of this deviation is due to the cooling of the sea water in the bucket before the thermometer was read. For taking the surface samples a canvas bucket was used and, as has been pointed out by others, the water in the bucket is cooled by evaporation at the outer surface. The rate at which the temperature decreases will vary with the force of the wind, the relative humidity, etc. On 9 occasions under varying conditions I found a decrease of 0.1° C. per minute. On 10 occasions the time was noted which elapsed from the moment the bucket left the surface until the thermometer was read. The interval was, on the average, 2½ minutes. It may thus be expected that the bridge observations will in general be 0.25° C. too low, due to the cooling of the water, a value in good agreement with the difference of 0.3° C. found by comparison with the records.

These results have also been checked in another way. Simultaneously with the bucket observations the surface temperature was observed with a reversing thermometer dragging over the surface at the end of a rope of about 10 metres length. In order to read the thermometer it was lifted from the surface by a second rope tied to the lower end. The thermometer reversed at the instant it left the surface. Although the thermometer was only dragging over the surface and even occasionally jumped into the air on the waves, I should not expect serious errors (by evaporation, radiation or other causes) in the temperatures observed in this way. Owing to the ship's motion a somewhat violent circulation of surface water along the bulb of the thermometer took place.

Only 20 observations were made, but they gave temperatures which are on the average 0.35 C. higher than the bucket observations. A constant error in the latter of about —0.3 ' C. seems therefore well established and we are justified in applying a correction of —0.3° C. to all surface temperatures observed on the bridge. Differences between the corrected bridge observations, the corrected records and the observations made with a reversing thermometer must be due to the irregular errors in the various methods of observation.

Comparing corrected bucket temperatures with reversing thermometer values the root mean square of the differences is only 0.1° C., while comparing the former with readings from the records a root mean square difference of 0.3° C. is found. The latter value is due partly to errors in the observations but partly also to irregular differences in temperature at the surface and at the depth of 1.2 metres. The former value of 0.1° C. seems to indicate that the corrected bucket observations must be fairly exact, the mean error not exceeding 0.1° C., a much better result than I should have expected.

An interesting feature of the records is shown in the reproductions from the 19th of May and the 2nd of June 1930 given in figures 3 b and 3 c. On these days rapid and rather irregular variations up to 2° C. occurred during the whole afternoon. Similar records were generally obtained on calm days; for instance, on the 19th of May the average velocity of the wind during 24 hours was only 1.5 m/sec. It is a well-known fact that under these circumstances the radiation of the sun will set up and maintain a high temperature gradient in the uppermost water layers. Differences of 2° C. in temperature at the surface and at 1 m. depth may exist and have been observed in certain cases by means of the reversing thermometer. The irregularities in the records reproduced are due to the effect of the turbulence set up by the movement of the ship or by the light winds still present. It has been pointed out by others that on calm days the temperatures recorded some metres below the surface do not give the real surface temperatures. In our case it may be seen at once from the records whether the temperatures registered are trustworthy or not as surface temperatures. Perhaps the irregularities found here are smoothed out when the thermometer is placed in the condenser intake. If this is the case the arrangement as used on board H. M. S »Snellius» is certainly of considerable advantage.

The different features of the records are most beautifully illustrated by the observations made during the passage through the narrow strait between the islands of Pantar and Alor (Strait of Pantar) on the 17th of December 1929. Since the ink of the thermograph was rather pale the original record cannot be reproduced here, but from 10 to 16 hrs. the temperature has been read for every minute and from these data the reproduction given in figure 4 has been constructed.

During the morning the weather was very calm and before entering the strait at 13.30 the record shows the irregular variations characteristic of calm days. In the strait sharp increases and decreases of 2 or even 3° C. were found; strong eddies could be seen on the surface. Coming out at the north side in the Banda Sea a gentle wind was blowing; correspondingly the record was regular and smooth.

From 12.50 till 15.20 a series of observations was made both with a canvas bucket (crosses) and with a reversing thermometer dragging over the surface (square dots). In the figure the correction of 1.25° C. has not been applied to the records.

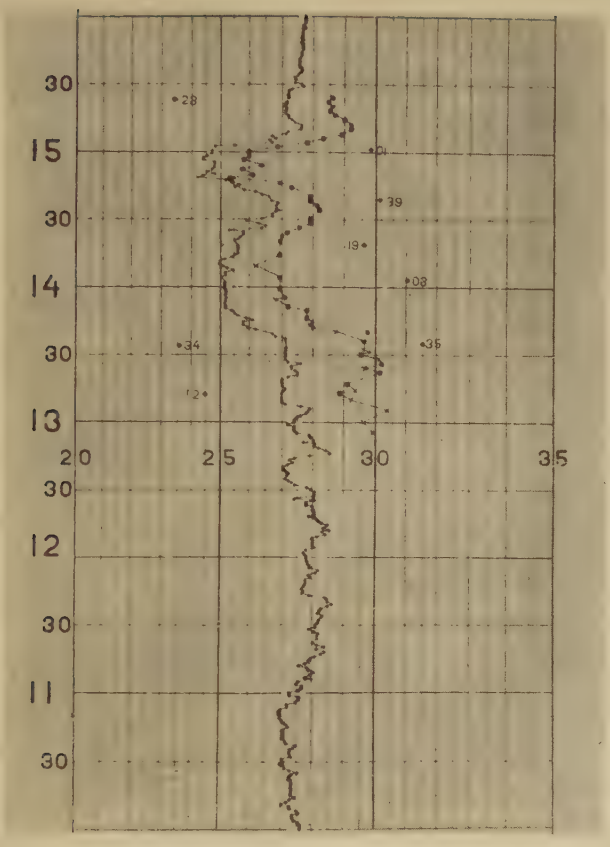

Fig. 4.

If we calculate the differences between records and observations for different intervals of time we obtain the following results.

	Differences observed	Differences after correction	Number of observ.
From 12.50—13.40	2.35° C.	1.1° C.	15
» 13.40—14.05	2.0° »	0.75° »	11
» 14.05—15.25	1.4° »	0.15° »	25

Thus, before entering the strait, a difference of 1.1° C. between the surface and a depth of 1.2 m. is found, due to the calm weather conditions; a high temperature gradient must have prevailed there near the surface. In passing through the strait, the difference gradually declines to 0.15° C., the value found in the Banda Sea. Probably the residual discrepancy of 0.15° C. is the result of systematic errors in the method of observation. Some of the observations with the reversing thermometer were made at intervals of only 2 minutes. Then the time was rather short for the thermometer to adapt itself completely to the surface temperature.

The canvas bucket observations were made with special care; the thermometer was read about half a minute after the surface haul was made. Simultaneous observations with bucket and reversing thermometer agreed very well, the mean difference being less than 0.1° C. In general the reversing thermometer gave a slightly higher temperature.

Eight points were deliberately put far outside the general temperature record to serve as reference marks concerning time. These are also reproduced in figure 4.

Summary.

A description is given of an electrical thermograph for sea surface temperatures. The resistance thermometer was fitted in a cubical recess specially made for the purpose in the side of the ship.

The galvanometer used was of the so-called cross-coil type; the readings from this instrument are independent of small variations in the voltage of the battery. It was found useful to suspend the recording galvanometer in a simple sort of gimbal ring.

To test the accuracy of the instrument, its readings have been compared with those of other methods, with generally satisfactory results.

Some interesting records are reproduced and discussed in detail.

The Circulation in the Depths of the Indian Ocean.

By

Helge Thomsen.

(From the Carlsberg Foundation's Oceanographical Expedition round the World 1928—30 under the Leadership of Professor Johs. Schmidt).

As is well known, a common feature in the hydrography of the oceans is the uniformity in temperature and salinity of the water-masses at depths greater than ca. 1500 m. To this uniformity, along with the technical difficulties of obtaining water samples and of measuring temperatures in the great oceanic depths, may be ascribed the fact, that even now — more than half a century after the Challenger Expedition — we still lack a sufficiency of reliable observations from the great depths to be able to give a well-founded description of the deep circulation in the Pacific and Indian Oceans. From the Atlantic, which has been worked over by a large number of more recent expeditions, we had obtained by the end of the »Meteor« expedition a material which far exceeded both in quality and quantity that available from the other oceans. The conclusions from this material with regard to the deep circulation in the Atlantic (1) have naturally quite a different degree of probability from the theories concerning the other oceans. One might think that a knowledge of the circulation in one would lead to analogous conclusions for other oceans, but the observations of the »Dana« and »Carnegie« (2) have shown that the Atlantic obviously occupies a special position in regard to the deep circulation.

A number of expeditions have worked in the Indian Ocean, the most important being the »Challenger«, »Vitiaz«, »Valdivia«, »Gauss«, »Planet«, »Möwe«, »Snellius« and »Dana«, but though the first four expeditions made important contributions to the hydrography of the Indian Ocean, the methods available in those days for the determination of salinities were not sufficiently accurate to give a reliable basis for conclusions regarding the conditions below ca. 1000 m., where differences in temperature and salinity become small and errors in determination thus come to have a greater significance.

Here we require at least the accuracy reached by means of the Mohr titration method, which was used on the last four expeditions. On the »Gauss« expedition titrations were also made along with physical determinations of salinity but unfortunately such large errors entered into the titrations that the physical determinations must be considered the more accurate.

After publication of the »Gauss« observations Schott (3), in 1926, on the basis of the material then available, drew a section along ca. 60° E. long, and from this, by analogy with the Atlantic, assumed a north-going bottom current and a south-going deep current with

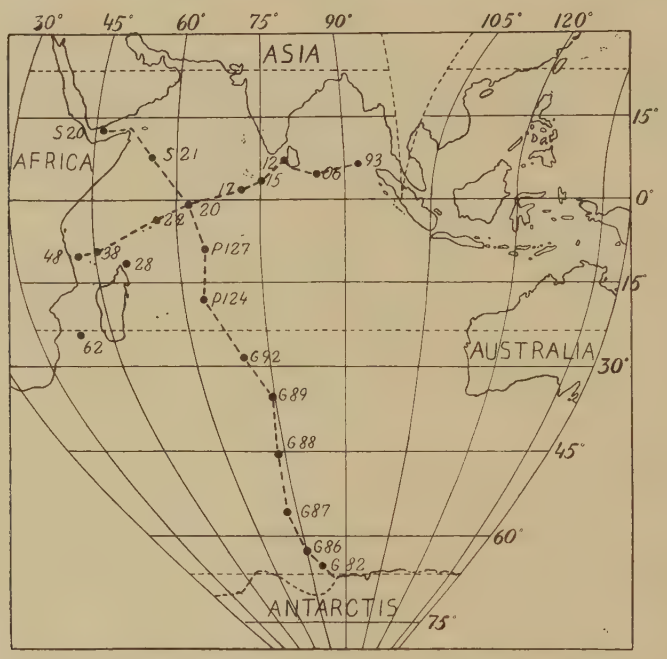

Fig. 1. Chart showing the Kerguelen section running from the Gulf of Aden to the Antarctic Continent and the "Dana" stations between the north point of Sumatra and Cape Delgado in East Africa. Da 39 ("93"—Da 38) is omitted from the "Dana" station numbers. G: "Gauss", P: "Planet". S. "Snellius".

nucleus at a depth of about 2500 m., which carries relatively salt water from the Arabian and adjacent enclosed seas southwards. This deep current is recognisable from its salinity maximum, which at 4° S. lat. lies at a depth of 2000 m. with a salinity of 35.00 $^0/_{00}$, and at 15° S. at a depth of approximately 2500 m. with a salinity of 34.80$^0/_{00}$. In latitudes farther south the maximum lies a little higher, thus at 59° S. at 1500 m. with 34.70 $^0/_{00}$.

Later (in 1929) Lotte Møller (4), subjected the whole of the available material from the Indian Ocean to a careful revision and

has published some sections, which confirm Schott's view of the deep circulation. In the Kerguelen section[1]) running approximately as shown on the chart, Fig. 1, we find likewise a maximum at a depth of 2000—2500 m. At ca. 9° S. it lies at a depth of approximately 1800 m., S = 35.00 ‰; at 15° S. in 2000 m. with S = 34.80 ‰; and lastly at 46° S. in 2000 m. with S = 34.70 ‰. In a second section, the Ceylon section, running from Ceylon in a south-westerly direction to ca. 57° S., 15° E., the 35.00 ‰ curve shows a maximum at ca. 800 m. at 6° S., but the 34.80 ‰ curve continues right down to 46° S., the layer between 2000 and 3000 m. having salinity greater than 34.80 ‰ right down to this latitude. This section has hitherto been taken as the most probable for the western half of the Indian Ocean (5) (2), in all probability because of the analogous conditions in the Atlantic, but when the »Dana« expedition under Johs. Schmidt was working in the Indian Ocean in 1929—30 it became evident that the last-mentioned section especially was quite misleading.

At a series of stations from the north point of Sumatra over to Cape Delgado in East Africa (Fig. 1), we found everywhere considerably lower salinities in deep water than were expected, and only at one of the stations (Da 3920) was a very slight admixture noted of water coming from the Red Sea, at the relatively small depth of ca. 1000 m. Fig. 2 shows the T-S diagrams for some of the stations on the section. Common to these stations is the condition that the T-S curves in the part nearest the bottom are rectilinear and coincident. For the two most northerly stations, Da 3893 and Da 3912, this is the case from ca. 400 m. to the bottom; for Da 3920 and Da 3938, where Antarctic water is noticeable (also Red Sea water at Da 3920), we find the curves rectilinear and coincident from 1500 and 2000 m. respectively down to the bottom. This condition of the T-S curves leads to the conclusion that the watermasses represented by the straight parts of the curves are pure mixtures of two well-defined waters, one of which is the bottom water *B* (T = 1.20°, S = 34.74 ‰), whilst the other must have a temperature and salinity corresponding to the other end *I* (T = 11°, S = 35.15 ‰) of the straight line. The determination of this end point is somewhat optional from the available material, as possibly *I* may lie higher up at other stations, but it is of minor importance in this connection.

This *I* water cannot come from the Red Sea, for the Red Sea water sinks down in the Indian Ocean to a depth of about 1000 m., whilst the *I* water occurs at a depth of about 400 m. at the north-eastern stations. Nor is it very probable that the very salt water of the Persian Gulf can play any part in the formation of the *I* water;

[1]) In this section Lotte Møller has obviously used the titrimetrically determined »Gauss« salinities, which are generally considerably lower than those determined physically. The remarkably low salinities in the deep water about 60° S. (S. < 34.4 ‰) must certainly be due to systematic titration errors — change in the concentration of the normal water used — as suggested by Drygalski.

we may suppose that this is formed in the Arabian Sea where we find sufficiently high salinities at the surface.

If a salinity maximum should occur in southern latitudes at a depth of 2500 m., due to water originating north-west of the section Ceylon to Cape Delgado, this must arise from *B—I* water moving southward. In southern latitudes the presence of the less salt antarctic

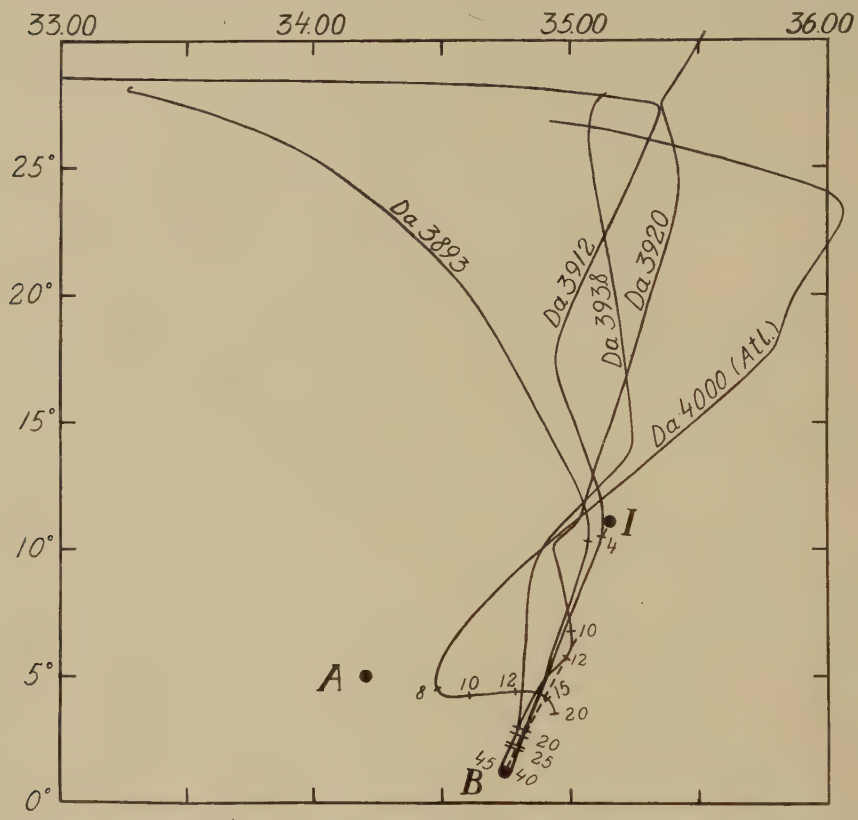

Fig. 2. T-S diagrams. A: Antarctic water, B: Bottom water. Small figures denote depths in hectometres.

water at depths of some 1000 m., will cause a salinity minimum at this depth, and this again — due to the inclination of the *B—I* line can cause a salinity maximum at a depth so far below the antarctic current that admixture of antarctic water ceases. In this way a salinity maximum might arise at 2500 m., but as the temperature at this depth according to M ø l l e r is ca. 2.5°, the maximum must be at most ca. 34.80 $^0/_{00}$ due to the situation of the *B-I* line, assuming also that there is no further mixing of the water at 2500 m. with the less salt masses above and below. If we assumed that it was Red Sea water — in the concentration found at station

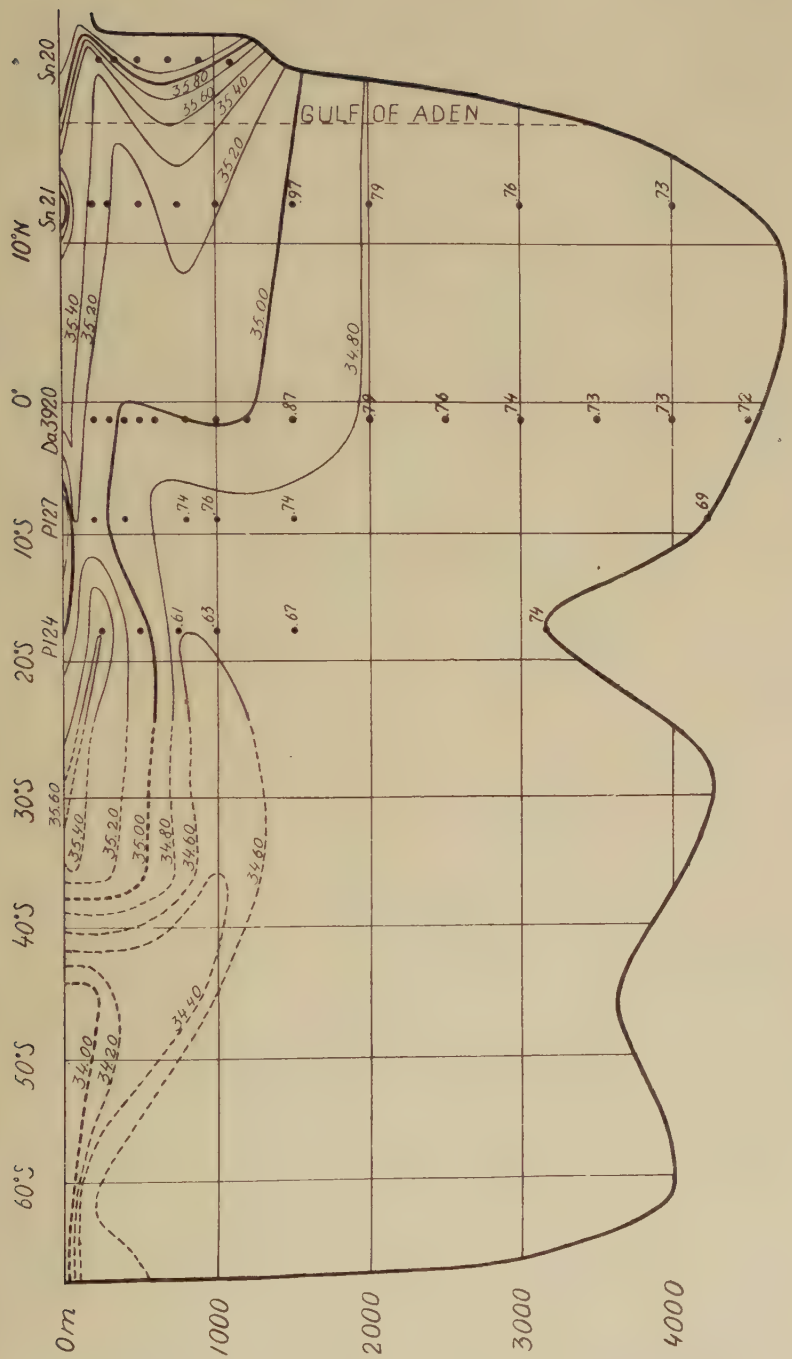

Fig. 3. The Kerguelen section. Salinity. Da: "Dana", P: "Planet", Sn: "Snellius".

Da 3920 at 1100 m. — which formed the salinity maximum at 2500 m. by mixing with bottom water, we could theoretically expect a maximum of at most 34.82 ‰ at 2500 m., but such a mixing is not very probable, as it is not found at the other stations of the section.

From these considerations we come to the conclusion that Lotte Møller's Ceylon section is misleading at least quantitatively, as we cannot carry the 34.80 ‰ curve south of the Cape Delgado—Ceylon section into greater depths than 2000 m.[1]). Fig. 2 also gives the T-S curve for the station Da 4000 (0°31′ S., 11°02′ W.) situated in the Atlantic almost at the same latitude as Da 3920 in the Indian Ocean. The marked difference between the Atlantic and the Indian Ocean in low latitudes appears directly from the diagram, and apart from the presence of the Antarctic intermediate current and the bottom current in both oceans there can be no question of any great resemblance between them. At a depth of 2000 m. at station Da 4000 we find T = 3.49°, S = 34.94 ‰ in contrast to T = 2.85° and S = 34.79 ‰. Unfortunately there are no observations from depths greater than 2000 m. for Da 4000, but according to Wüst we may conclude that the salinity in 2500 m. is a little greater, whereas at Da 3920 it is less, namely 34.76 ‰, so that the difference between the two oceans is still greater at 2500 m. than at 2000 m.

Fig. 3 displays the salinity in a section running from the Gulf of Aden over Kerguelen to the Antarctic, as marked on the chart, Fig. 1. The new observations from the »Dana« and »Snellius« (7) fill up a gap, so that it is now possible with some certainty to draw the isohalines down to ca. 25° S. The observations come from different seasons, but at great depths the seasons of the year make very little difference in the salinity. In the Gulf of Aden on the other hand the salinity varies with the time of year, as shown by van Riel (7), among others. The southern part of the section is based essentially on the »Gauss« salinities determined physically, and the isohalines therefore — especially in the depths — cannot be drawn with the same certainty as in the northern part. It appears from the section that Red Sea water penetrates southwards in depths around 500—1000 m., but stops in its advance almost at the equator where it meets with the Antarctic current. In depths greater than 2000 m. the water is very homogeneous in regard to salinity, which everywhere lies between 34.60 and 34.80 ‰. As the deep current hitherto supposed to be moving south in the Indian Ocean at depths between 2000 and 3000 m. cannot, according to the new observations, be detected from high salinities as

[1]) It can scarcely be accidental that the 34.80 ‰ curve just in the Ceylon section continues so far south (to 46° S. L. against 16° S. L. in the Kerguelen section), as this section in its south western part undoubtedly contains water coming from the Atlantic deep current; salinities greater than 34.80 ‰ are thus probable in this part between 2000 and 3000 m. but not north of about 20° S. L.

It may be mentioned that Merz (6) has also drawn the Ceylon section but more correctly has not carried the 34.80 ‰ curve into depths greater than ca. 1600 m.

in the Atlantic, and the Indian Ocean hydrographically cannot be said to resemble the Atlantic to any great extent, a very essential basis for the assumption of the existence of this current is done away with. Whether we can still support the view of its existence simply as compensation current for the water masses which the bottom current, the Antarctic intermediate current and the southern, subtropic salt current carry northwards, future investigations must decide.

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Experimentelle Beeinflussung von Schuppenbildern.

Von

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Buitenzorg auf Java (N. I.)

An Schuppen junger Karpfen war aufgefallen, dass auch in den Tropen Zonen weiterer und engerer Schuppenring-Anlagen entstehen können, sodass Bilder zustandekommen, die bei flüchtiger Betrachtung an die Sommer- und Winterzonen auf Schuppen mehrjähriger europäischer Karpfen erinnern. Ferner konnte festgestellt werden, dass schnelleres oder langsameres Wachstum von Karpfenindividuen, die in bestimmten Abständen gewogen und gemessen wurden, sich deutlich durch Zonen weiterer und engerer Ringanlagen wiederspiegelt.

Diese Wahrnehmungen führten zu einer Reihe von Experimenten, bei denen das Wachstum von Karpfen *willkürlich beeinflusst* wurde, z. B. durch verschiedene Fütterung und verschiedene Wahl des Aufenthaltsraumes. So wurden Karpfen von der Geburt an 18 Tage im Teich gehalten und dann in ein Aquarium verbracht, wo sie 36 Tage lang und länger verblieben. Es stellte sich heraus, dass in den 18 ersten Tagen mehr als 18 — in einem Fall z. B. ca. 22 — Ringe um die Kernzone der Schuppe herum angelegt werden können, während in den folgenden 36 Tagen ca. 9 Ringe gebildet wurden. Letztere liegen viel enger beieinander als erstere. Beide Gruppen sind durch eine ganz schmale dunkle Zone geschieden, die man sich damit zu erklären hat, dass das Wachstum im Aquarium zunächst ganz abgestoppt wurde, bis der Fisch sich an die neuen Verhältnisse gewöhnt hatte und wieder zur Futteraufnahme überging. In anderen Fällen wurden in 36 ersten Lebenstagen, die im Teich zugebracht wurden, ca. 36 Ringe in geräumigen Abständen angelegt, während innerhalb weiterer 72 Tage ca. 12 eng aufeinanderfolgende Ringe gebildet wurden. Vorübergehender Aufenthalt im Aquarium und vorübergehender Nahrungsmangel im Teich zeichnen sich auf der Schuppe durch eine engringige Zone ab, die zwischen weiterringigen gelagert ist. Auch klimatische Einflüsse, welche das Wachstum verlangsamen, werden durch

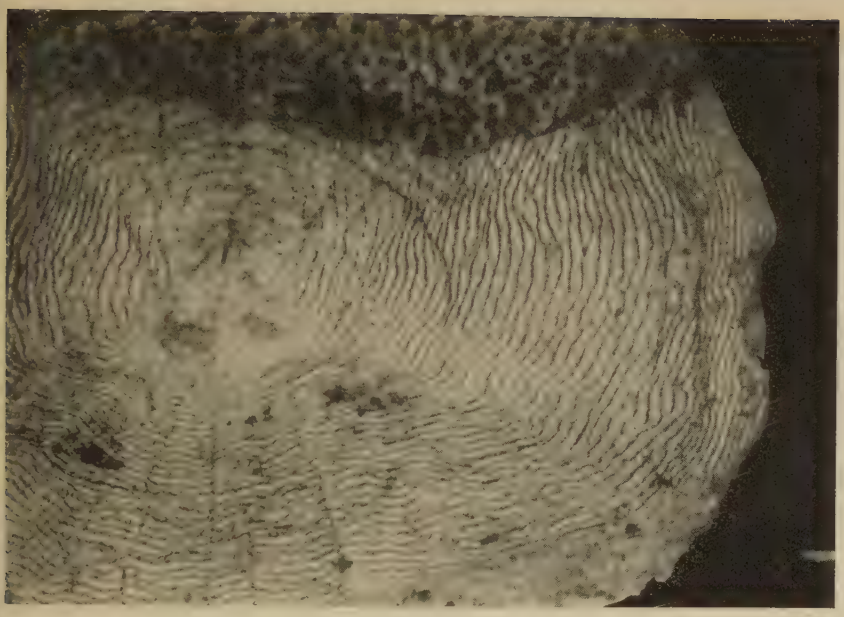

Abb. 1. *Cyprinus carpio* L. Schuppe. Der Fisch war 36 Tage in einem Teich (ca. 38 Ringe) und dann 36 Tage im übersetzten Teich (ca. 9 Ringe).

die Abstände zwischen den Schuppenringen genau wiedergespiegelt. Praktisch am belangvollsten ist die Tatsache, dass Fische, welche infolge ihres Heranwachsens im Futterbedarf so zunehmen, dass dieser durch den Naturfuttervorrat im Teich nicht mehr voll gedeckt wird, daran zu erkennen sind, dass die Schuppenringabstände von einem gewissen Moment ab mehr und mehr abnehmen. Fischt man solche Fische ab und setzt man sie in geringerer Anzahl auf die Oberflächeneinheit berechnet wieder aus (vgl. »Ausdünnen« oder »Pikieren« im Gärtnerei- und Forstbetrieb), sodass sie danach wieder reichlich Nahrung finden, so entsteht dasselbe Bild wie es der Jahreszeitenwechsel in Europa auf der Fischschuppe hervorruft (sogen. »Winterringe«), nämlich ein allmähliches Abnehmen (Herbstabklingen) der Ringabstände, dem plötzliche starke Zunahme der Ringabstände folgt (Frühjahrswachstum). Schon kleine, dem Experimentator verdeckt bleibende Wachstumsschwankungen im Aquarium, Teich und See lassen die Schuppe des Tropenfisches mehrzonig erscheinen, sodass bei schnellgewachsenen Exemplaren innerhalb eines Mussons (z. B. *innerhalb* der Trockenzeit oder *innerhalb* der Regenzeit) verschieden weit beringte Zonen auf der Schuppe entstehen. Somit darf Mehrzonigkeit nicht als Beweis dafür angesehen werden, dass der Fisch mehrere Mussons hinter sich hat. Abgabe von Geschlechtsprodukten führt in der Regel zu einer gewissen Wachstumsunterbrechung, die gleichfalls auf der Schuppe ihre Wiederspiegelung erfährt.

Das »Laboratorium f. d. Binnenfischerei« zu Buitenzorg setzt die Experimente fort und bereitet eine ausführlichere Publikation darüber vor[1]).

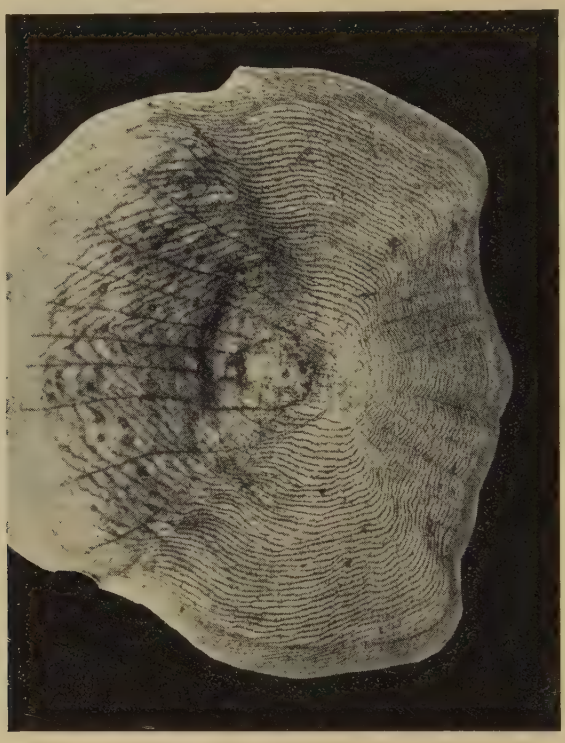

Abb. 2. *Cyprinus carpio* L. Schuppe. Der Fisch war 36 Tage in bestem Teich (ca. 38 Ringe) und dann 65 Tage im Aquarium (ca. 6 Ringe).

[1]) s. Internat. Revue, Bd. 27, Heft 4/6. S. 427 (1932).

Reife Lachse *(Salmo salar)* in Teichen.

von

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Dänische Biologische Station, Abt. f. Binnenfischerei.

In den seltensten Fällen nur wird es möglich sein, den vorhandenen Lachsbestand zu erhalten, geschweige denn zu vergrössern, ohne künstlich erzeugte Brut auszusetzen. Aber die Beschaffung der hierfür erforderlichen Menge von befruchteten Lachseiern stösst auf bedeutende Schwierigkeiten, teils weil die Zuchttiere kostbar sind, teils weil sie nur ausnahmsweise in reifem Zustande gefangen werden und beim Halten bis zum Eintreten der Reife erfahrungsgemäss grosser Sterblichkeit ausgesetzt sind. Und so erhebt sich die eine Klage nach der andern, dass die gewünschte Menge Lachsrogen nicht mehr zu beschaffen ist. Es muss daher als ein Fortschritt bezeichnet werden, dass es nun geglückt ist, Lachse in Teichen zu ziehen und als Zuchttiere zu benutzen.

Ob man schon früher versucht hat, Lachs über die Setzfischgrösse hinaus zu züchten, entzieht sich meiner Kenntnis. Es wäre anzunehmen, aber ich habe keine Beweise dafür in der Literatur gefunden. Buschkiel (Salmonidenzucht in Mitteleuropa. 1931. S. 320) schreibt, dass die Bezeichnung »Teichlachse« nicht zu Missverständnissen führen darf — sie gilt nicht dem *Salmo salar*, sondern grösseren Exemplaren von *Salmo irideus*. Man kann wohl annehmen, dass dieser oder jener im Laufe der Zeit versucht hat, einige der zum Aussetzen in freies Wasser bestimmten Setzlachse noch eine Weile im Teich zu behalten; aber die Tiere sind ohne Zweifel schlecht gewachsen und die weitere Zucht ist dann vermutlich aufgegeben worden: konnte ein rasches Wachstum nicht erzielt werden, bestand unter den damaligen Verhältnissen kein Interesse daran, die Fische im Teich zu halten.

Im Frühjahr 1932 hörte ich, dass es einem dänischen Fischzüchter geglückt sei, sich von Lachsen, die er in seiner Teichwirtschaft hielt, befruchteten Rogen zu beschaffen. Eine kurze Mitteilung darüber gab ich im »Ferskvandsfiskeribladet« (1932, Nr. 6), aber erst nachdem ich am 14. August Gelegenheit gehabt hatte, mich durch Augenschein zu vergewissern, dass es sich wirklich um *Salmo salar* (und nicht um lachsähnliche Forellen) handelte, gab ich in derselben Zeitschrift (Nr. 10) eine eingehendere Beschreibung.

Der erwähnte Fischzüchter heisst S. Nissen Jøker und seine

Teichwirtschaft liegt in Spjarup bei Egtved (Jütland, ca. 20 km nordwestlich von Kolding). Die Teichwirtschaft ist schon älter, ist aber in neuerer Zeit vergrössert worden. Das Wasser, das benutzt wird, ist teils Auwasser (von der Egtved Au), teils Quellwasser von den umliegenden Hügeln; weder hierin noch in anderer Weise unterscheidet sich diese Wirtschaft scheinbar von den vielen andern jütischen Forellenteichen. In dem einen Teich, der vielleicht 100 Quadratmeter gross und gegen 1 m tief sein mochte, schwammen die Lachse — Männchen und Weibchen zusammen, Tiere von ungefähr ¾—1¼ Kg. das

Fig. 1. Lachs *(Salmo salar L)*, ♀ — ♂, 42 cm, ca. 725 g, kaum 5½ Jahre alt. Spjarup Forellenteichwirtschaft, den 14. August 1932.

Stück. Sie waren sehr lebhaft und befanden sich zweifellos wohl. Ungefähr zwei Wochen vor meinem Besuch, also um den 1. August herum, hatten sie aufgehört zu fressen, ein Zeichen für das Herannahen der Laichzeit. Da man sie also nicht mit dem Ketscher fangen konnte, wenn man Futter auswarf, musste der Wasserstand gesenkt werden, ehe sie genommen werden konnten; auf diese Weise sah ich einige Exemplare auf dem Lande. Einen nahm ich mit mir, um ihn am folgenden Tage näher zu untersuchen und zu photographieren. Das Bild ist unten wiedergegeben, und die Untersuchung ergab, dass die Merkmale, die am besten Lachs *(Salmo salar)* von Forellen *(Salmo trutta)* trennen, alle eindeutig auf Lachs zeigten. So war der Oberkiefer kurz, der Schwanzstiel schlank, die Schwanzflosse hatte spitze Gabelung und die Afterflosse war verhältnismässig klein — was alles auf der Photographie zu erkennen ist. Ausserdem waren die Schuppen verhältnismässig gross, sodass zwischen der Fettflosse und der Seitenlinie nur 12 Schuppen gezählt wurden (die durchbohrte mit einberechnet), und sowohl die obersten wie die untersten Fortsätze an der Innenseite des ersten Kiemenbogens waren stäbchen- nicht warzenförmig; vgl. Figur 2. Alle diese Kennzeichen beweisen übereinstimmend, dass es sich hier um einen echten Lachs handelt.

Die Geschichte der Teichlachse ist wie folgt: — 1926 wurde im Vejle Fjord ein reifes Lachsweibchen von ca. 4 Kg. gefangen und gleichzeitig ein Lachsmännchen von ca. 7 Kg. Lachse kommen nur selten in den Vejle Fjord hinein, es können Jahre zwischen ihrem Vorkommen liegen. Es war also ein glücklicher Zufall, dass die Fänge so nahe zusammen fielen, dass das Männchen zur Befruchtung des Rogens verwendet werden konnte. Nach Abstreifung und Befruchtung kamen die Eier — ca. 6000 — zur Erbrütung zu J. P. Nissen Jøker, Kildevæld bei Vejle. Im Frühjahr 1927 wurde dann die aus-

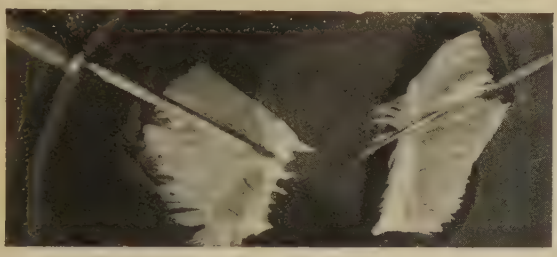

Fig. 2. Erste linksseitige Kieme des in Fig. 1 abgebildeten Lachses. Sie ist quer durchgeschnitten, der oberste Teil ist unten links, der unterste unten rechts. Man sieht, dass die Fortsätze an der inneren Seite nicht nur in der Mitte, sondern auch am obern und untern Ende stäbchenförmig sind. — Etwas vergrössert.

geschlüpfte Brut — ca. 6000 Stück — in Teiche von M. Nissen Jøker, Hvilestedgaard bei Ejstrup, ausgesetzt. Erst als die Fische zwei Jahre alt waren, kam ein Teil — ca. 300 Stück — zu S. Nissen Jøker in Spjarup; von den übrigen sind einige vielleicht noch in anderen Teichwirtschaften. In Spjarup befanden die jungen Lachse sich wohl, sie waren lebhaft und frassen gut, nur wollten sie nicht recht wachsen. Schon im Herbst 1930 reiften die ersten, nämlich einige Weibchen und alle Männchen. Das Abstreifen gelang insofern recht gut, als ein Satz guter Eier erzielt wurde, machte aber Schwierigkeiten, indem die Weibchen, die offenbar sehr empfindlich waren, leicht nach dem Abstreifen eingingen. Diese Schwierigkeit meint Nissen Jøker indessen überwunden zu haben; man muss nur vorsichtig und schnell arbeiten, dann geht es; beim Abstreifen im Jahre 1931 war der Verlust an Mutterfischen nur gering. In dem Jahr reiften alle Lachse, und es wurde wieder eine Partie guter Rogen gewonnen. Jetzt, Ende 1932, wurden die Lachse zum dritten Mal reif. Die erste Abstreifung fand Mitte November statt (ungefähr ein Viertel der Fische), die zweite Mitte Dezember (etwas über die Hälfte der Fische); die letzten Fische werden ungefähr am 20. Januar abgestreift werden. Die Eier dieses dritten Laichs sind mindestens ebenso gross wie die des zweiten und etwas grösser als die des ersten Laichs. Ihre Befruchtung gelang prozentual diesmal besser als früher; Nissen Jøker wagt aber nicht zu sagen, ob es daher kommt, weil die Lachse kräftiger waren, oder ob er vielleicht mehr Glück hatte.

Der Rogen dieser Teichlachse hatte, wird gesagt, dieselbe ansehnliche Grösse wie Rogen von Wildlachs; dafür war dann natürlich die Anzahl nicht so gross. Man rechnet im allgemeinen bei Lachsen etwa 1000—2000 Eier auf das Kg. Weibchen, und da die Teichlachse gerade um 1 Kg. das Stück wiegen und ca. 100 Weibchen da sind, konnte man die diesjährige Gesamterzeugung auf ungefähr 100,000—200,000 Eier schätzen. Die Berechnung stimmt, denn in diesem Jahre werden etwa 150,000 lebenstüchtige Eier gewonnen werden. Einen Teil der Eier

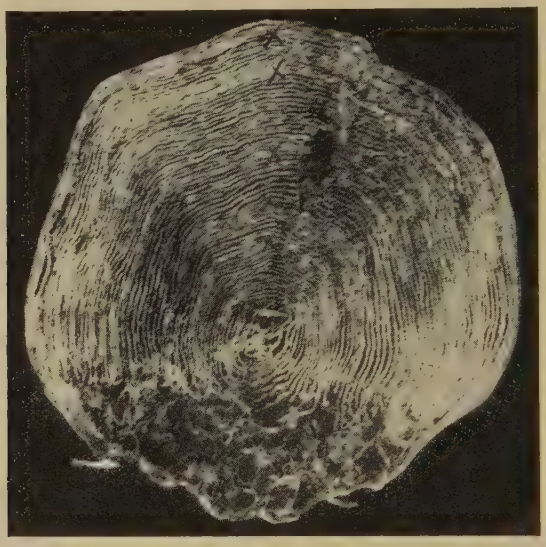

Fig. 3. Schuppe eines Teichlachses, ♀, 42 cm, kaum 5½ Jahre alt. Spjarup Forellenteichwirtschaft, den 14. August 1932. Die fünf × markieren die Jahresringe.

der früheren Abstreifungen hat Nissen Jøker verkauft, einen Teil aber behalten; die daraus entstandene Brut war gross und kräftig und wird nun weiter in Spjarup aufgezogen, wo jetzt also ein Teich voll von Lachsen dieser zweiten Generation von Teichfischen (jetzt zwei Jahre alt) heranwächst; die grössten messen jetzt 24 cm.

Während der Reifungszeit des ersten Jahres, also 1930, waren die Lachse so unruhig, dass es fast unmöglich war, sie im Teich zu halten; besonders in kalten und stürmischen Nächten sprangen sie bis auf die Böschung herauf. So etwas hat man später nicht mehr bemerkt.

Es wird nun interessant sein zu verfolgen, wie lange die Lachse beibleiben können, Rogen zu liefern. Bei den Wildlachsen kommt es nicht häufig vor, dass man Exemplare findet, die 2 mal gelaicht haben, und ein Lachs, der das dritte Laichen überstanden hat, ist meines Wissens nur ein oder zwei Mal gefunden worden. Es ist nicht belanglos zu untersuchen, wie die Schuppen der Spjarup-Lachse aussehen. Figur 3 und 4 geben Photographien einer Schuppe des in Figur

1 abgebildeten Lachses. Man sieht die Jahresringe, die dem bekannten Alter (ca. 5½ Jahre) entsprechen. Während aber die gewöhnliche Lachsschuppe Unterschiede zeigt zwischen dem langsamen Wachstum der Jugendjahre (im Flusslauf) und dem schnelleren Wachstum

Fig. 4. Linke Seite der in Fig. 3 wiedergegebenen Schuppe. Die Unregelmässigkeiten in den Jahresringen sind vermutlich als Laichmarken zu verstehen.

der späteren Jahre (im Meere), findet man nichts dementsprechendes auf der hier abgebildeten Schuppe. Ebensowenig zeigt sie deutliche Laichmarken, obwohl der Fisch 1931, vielleicht auch 1930 gelaicht hat. Huitfeldt-Kaas (siehe unten) konnte Laichzeichen bei Süsswassermännchen nachweisen, aber das Laichen scheint die Teichlachse nicht annähernd so stark mitzunehmen, wie die Lachse im freien Wasser. Die Spjarup-Lachse haben ihr zweites Laichen ganz vorzüglich überstanden; auch das dritte haben die schon abgestreiften gut überwunden — nur vier davon (ein Weibchen und drei Männchen) starben und die andern fressen schon gut; es ist schon zu sehen, schreibt Nissen Jøker in einem Brief vom 18. Januar, dass die Fische, besonders die Weibchen, angefangen haben, das blanke Sommerkleid anzulegen. Es hat daher nicht den Anschein, als ob die Fische daran

denken, an Alter einzugehen; die meisten werden nach dem dritten Laichen weiter leben. So ist es nicht im freien Leben, aber die Bedingungen, unter denen die Teichlachse ihre Laichzeit zubringen, sind unleugbar viel leichter als die, die dem Wildlachs zu teil werden. Wir dürfen also hoffen, dass die Teichlachse eine längere Reihe von Jahren zur Rogenproduktion werden dienen können.

Warum hat man nicht früher Lachsweibchen bis zur Reife aufgezogen? Lachsmännchen zu Reife zu bringen ist nicht schwer. Hier in Dänemark kennen wir z. B. einen Fall aus dem Jahre 1908, von der Villestrup Au, wo Lachsbrut in einer abgesperrten Strecke ausgesetzt wurde; unter diesen Lachsen, die nicht im Meere gewesen waren, befanden sich reife Männchen (Danmarks Fauna, Fisk II, 1914, S. 131). In norwegischen Elven fand Knut Dahl (Laks og Laksefiske. 1929, S. 18) sogar unter 117 nicht ausgewanderten Lachsmännchen 56 Stück mit geschwollener Milch. Huitfeldt-Kaas (Vekst- og aldersundersøkelser hos vore ferskvandssalmonider. 1914, S. 11) fand auch viele und konnte sogar nachweisen, dass diese Süsswassermännchen Laichzeichen bekommen konnten und — ohne auszuwandern — mindestens zwei Male laichen konnten; es ist sogar wahrscheinlich, dass einige von ihnen überhaupt nicht auswandern. Ant. Fritsch (Der Elblachs. 1893. S. 72) schildert, wie man in Böhmen häufig die leicht zu beschaffenden Kleinlachse (Strdlice, Struwitzen) zur Lieferung von Milch benutzte, wenn man reife Lachsweibchen hatte. De Bouville aber hat bei der Besprechung (Élevage du Saumon en vivier. Bulletin français de pisciculture, Octobre 1932) meines Berichtes darauf aufmerksam gemacht, dass schon Conrad Gesner (Historia animalium liber III qui est de piscium et aquatilium animantium natura. 1558. S. 970) und später Duhamel du Monceau (Traité général des pêches avec l'histoire des poissons qui y vivent. 1760—1771) gewusst haben, dass nicht ausgewanderte Lachsmännchen reif werden konnten, nicht ausgewanderte Lachsweibchen dagegen nicht. Man kann wohl annehmen, dass solche süsswasserreifen Männchen in allen Lachsbeständen in grösserer oder kleinerer Anzahl vorkommen. — Lachsweibchen dagegen, die reif wurden, ohne im Meere gewesen zu sein, hat man nicht gekannt, es sei denn in den Lachsbeständen, die in gewissen grossen Seen (Ladoga, Venern, den nordamerikanischen Seen) vorkommen, sowie in dem Bestand, den Knut Dahl vor wenigen Jahren in dem norwegischen See »Byglandsfjord« nachwies (The »Blege« or Dwarf-Salmon. A landlocked Salmon from Lake Byglandsfjord in Setesdal. Skrifter utgitt av Det Norske Videnskaps-Akademi i Oslo. I. Matem.-Naturv. Klasse. 1927. No. 9). Indessen schreibt de Bouville an der oben genannten Stelle, dass er vor einer Reihe von Jahren Gelegenheit gehabt hat, eine diese Frage berührende interessante Beobachtung zu machen. Er hatte im Jahre 1908 einige Lachsbrut in einem kleinen Bassin ausgesetzt, wo sie schlecht gedieh, und trotzdem waren im Herbst 1909 noch einige Exemplare am Leben. Sie hatten nur eine Länge von ca. 15 cm., ihre Köpfe waren zu gross, und sie hatten das Brutkleid noch nicht abgelegt.

»Quelle ne fut pas notre surprise de trouver deux de ces survivants en instance de fraye! L'un donna quelques gouttes de laitance, l'autre une vingtaine de gros oeufs, sains d'apparence. La fécondation artificielle échoua.« De Bouville fügt hinzu, dass dieser Fall beweist, wie die Laichzeit unter gewissen Bedingungen schon im zweiten Jahre einsetzen kann, wenn es auch als Anomalie anzusehen ist.

Unsere Forelle *(Salmo trutta)* tritt unter drei Formen auf: als Meerforelle (f. *trutta*), Seeforelle (f. *lacustris*) und als Bachforelle (f. *fario)*. Ob etwas Ähnliches wohl für die Lachse gilt? Der typische Lachs entspricht recht gut der Meerforelle, und der Seeforelle entspricht der »Seelachs« der grossen Seen (Ladoga, Venern, nordamerikanische Seen). Die in Süsswasser gereiften Lachsmännchen entsprechen in gewisser Weise den Bachforellen. Ebenso die Zwerglachse des Byglandsfjordes; diese werden nur ausnahmsweise grösser als 30 cm. und schwerer als ¼ Kg., also nicht so gross wie die Spjarup-Lachse. Es ist wahrscheinlich die Nahrungsmenge, die in erster Linie diesen Unterschied bedingt; sie ist reichlich in den Teichen (gehackter Fisch), aber vermutlich recht knapp im norwegischen See, wo sie aus *Bosmina, Chironomus* und verschiedenen Landinsekten besteht. Dass die Teichlachse trotz des reichlichen Futters lange nicht so stark wachsen wie die Wildlachse im Meere, ist wohl eine Folge des mystischen »Raumfaktors«. Und hier haben wir dann vielleicht den Grund, weswegen frühere Zuchtversuche missglückt sind. Man hat wahrscheinlich die Geduld verloren, als die Lachse so schlecht wuchsen und hat die Zucht nach einigen Jahren, ehe die Weibchen reif wurden, aufgegeben. Früher hat auch kein Grund vorgelegen, kleine Lachsweibchen aufzuziehen, denn der Zugang von grossen Wildfischen war ausreichend; jetzt, wo es immer schwerer wird, den notwendigen Rogen zu beschaffen, um die Flussläufe mit Brut zu versehen, hat es eine gewisse Bedeutung, dass Rogen von Teichlachsen beschafft werden kann, selbst wenn es nicht viel ist. Die Erfahrung hat uns nun gelehrt, dass es zu machen ist, und so sollte nichts im Wege sein, dass man an vielen Stellen Lachs bis zur Reife aufzieht und dadurch den Flussläufen die Brut zum Aussetzen sichert, die nötig ist, wenn der Lachsbestand in vernünftiger Weise gepflegt werden soll. Die praktische Bedeutung von S. Nissen Jøkers Lachszucht scheint daher nicht unerheblich zu sein.

On the Influence of Various Physical Factors on Cod Larvae; Experiments at the Flødevig Sea-Fish Hatchery.

By

Alf Dannevig and Erling Sivertsen.

A. The Influence of Light.

In Journal du Conseil No. 1, 1932, (The Influence of Light on the Cod) Dannevig described experiments showing that the cod, both larval and adult, reacts to the strength and direction of light, both natural as well as artificial.

This winter (1932) more experiments were made on the same lines, some of which are now to be described.

A wooden box, of internal dimensions[1]) 5×21×297 cm., was constructed with open ends and painted black inside. The box was placed in the lobster rearing room, which is not artificially heated, one end of the box being placed near a window facing south, the other end turned directly away from the window. Seven glass jars, 5×19.5 ×26 cm.[1]), were placed in the box at equal distances apart, jar no. 1 near the window, no. 7 at the farther end.

Two experiments, nos. 9 and 10, were made with the wooden box open to the light. In experiments nos. 11 and 12 a cover was placed on the top of the box, so that the light was only permitted to enter through the openings at each end.

The results of experiments nos. 10 and 12 are given in tables 1 and 2. The figures give the observed temperatures; in some cases this was a few tenths of a degree lower at the bottom. One asterisk indicates a concentration of larvae, double asterisks strong concentration.

As the light came in from the left, an asterisk on the left of the column in the table means a concentration towards the daylight. The occurrence of dead larvae is indicated by a cross (†).

Experiment No. 10.

On the 29th of March some larvae about 3 days of age (for further details see journal of the hatchery, apparatus no. 22) were placed in an iron basin in the lobster rearing room. The specific gravity of the sea water was 1.0273 at a temperature of 5.5° C.

On March 30th at 11.00 hrs. about 50 specimens were transferred to each of the jars, the water temperature being 5.3° C. and the specific gravity 1.0272. The larvae remained near the surface and were

[1]) i. e. width × height × length.

Table 1. Experiment 10.

Started March 30th at 11^{00} hrs. Specific gravity of the water 1.0272, temperature 5.3° C.

Date and weather	Hour	Number of jar; no. 1 nearest window: 1	2	3	4	5	6	7
March 30. Rain	12^{00}	*	*	*	*	*	* *	*
	14^{00}	* 5.3	* 5.2	* 5.2	* 5.1	* 5.2	* 5.1	5.1 *
	17^{00}	* 5.2	* 5.1	* 5.1	* 5.0	5.0	* 5.0	5.0 *
March 31. Rain	9^{00}	* 4.7	* 4.7	* 4.7	* 4.7	* 4.7	* 4.7	4.7 *
	17^{00}	* 5.3	* 5.3	* 5.3	* 5.3	* 5.3	* 5.3	5.3
April 1. Bright sky	8^{30}	* 3.7	* 3.9	* 4.0	* 4.0	* 4.0	* 4.0	* 3.9
	10^{00}	* 5.0	* 4.2	* 4.0	* 4.0	* 4.0	* 4.0	* 4.0
	11^{30}	10.4 *	7.4 *	* 6.0 *	* 5.5	* 4.8	* 4.6	* 4.4
	13^{00}	15.0 † ?	11.9 *	8.8 *	10.8	8.9	* 6.0	* 6.0
	16^{30}	16.0 †	10.2 *	* 9.3 *	* 9.3 *	* 8.5 *	* 7.3 *	7.1
April 2. Cloudy partly sunshine	10^{00}	all dead	4.5 †	* 4.2 *	4.2 †	* 4.0 *	* 3.6 *	* 3.6
April 4. Cloudy	12^{00}	all dead	all dead	* 3.2 * †	2.9 †	* 2.9 †	* 2.8	2.8
April 4. Percentage survival:	15^{00}	0	0	45	8	31	90	100

very lively. The detailed results, conditions of light, weather etc. are shown in table 1. The experiment was discontinued after 5 days.

Looking at the final results, it is evident that in the jars near the window the larvae did not thrive. It is reasonable to assume that the strength of the light, or the accompanying high temperatures, were unfavourable.

In order to examine the effect of high temperatures in the absence

of direct sunshine, some larvae were placed in a jar as used for the experiments described above and placed in the laboratory on the evening of the 1st of April, the laboratory being at ordinary room temperature. The next day at 10.00 hrs. the temperature was 14°, when the larvae were all well. One died at 13.00 hrs., the temperature then being 16°. The remaining larvae were lively. On the 3rd of April at 14.00 hrs., temperature 14.3°, the larvae were still alive, but somewhat pale. On the 4th of April at 9.00 hrs. temperature 13.8°, most of the larvae were dead.

As the larvae survived in the water of 16° in the laboratory on the 2nd of April, it is reasonable to make the direct sunshine responsible for the great mortality in the jars close to the window. As will be seen, the highest temperature in jar no. 1 was also 16°, but death had already occurred at 15°. In jar no. 2 also all the larvae died though the temperature here did not exceed 12°. All the larvae died in a few hours.

Jar no. 3 gave better results, however, than jars nos. 4 and 5. It will be seen that on the 1st of April at 13.00 hrs. the temperature in this jar was distinctly less than in the other two jars. This was apparently brought about by the shadow of the horizontal cross-frame of the window. The temperature was lower and the light weaker in jar no. 3 than in no. 4, especially at noon.

The concentration of larvae in the jars was quite regular, apparently governed by definite laws. In jar no. 1, there was a maximum on the window side until 10.00 hrs. on the 1st of April, after which there was a second maximum, on the other side. The light from the window being apparently too strong. The same occurred at 13.00 hrs. in the other jars, at far as jar no. 5, but to a decreasing degree as we pass away from the window. At 16^{30}, however, some larvae once more turned towards the light. (Nos. 3 & 5).

In jar no. 7 the diffuse light coming from the room was stronger than that coming from the window. As there were no end boards in the wooden box, the right-hand end of the jar was wholly exposed to the light from the room. Accordingly the larvae generally accumulated towards the right.

This experiment shows that the diffuse daylight about the 1st of April in our latitudes (58°25′) is attractive to the cod larvae when filtered through ordinary window glass. Sunshine, however, is disagreeable under the same circumstances.

Experiment No. 12.

In order to study the effect of artificial light, an Osram »Vitalux« lamp was placed at a distance af 20 cm. from the inner end of the wooden box and lighted at intervals as recorded in table 2. In this case a cover was placed on the box.

The jar to the left, near the window, was placed 20 cm. from the end of the box, to avoid direct sunlight. The wooden cover was in place, except when inspections were made.

Table 2. Experiment 12.

Date and weather	Hour	Number of jar: no. 1 nearest window: 1	2	3	4	5	6	7	Vita-lux:
April 6. Cloudy, partly sunshine	16^{30}	7.0	7.0	7.0	7.0	7.0	7.0	7.0	
April 7. Partly sunshine	9^{00}	4.5	4.4	4.3	4.3	4.3	4.3	4.3	
	17^{00}	7.3	6.3	6.2	6.1	5.9	5.6	5.7	
April 8. Sun	11^{30}	5.1	4.9	4.9	4.7	4.7	4.6	4.6	
April 9. Sun	10^{50}	4.1	3.6	3.5	3.4	3.3	3.3	3.2	put on
	12^{00}	5.7	4.8	4.2	4.2	3.8	3.9	8.3 - 4.3	
	13^{00}								off
April 11. Partly sun and rain	11^{00}	6.5	6.1	6.0	5.9	5.9	5.8	5.7	
	16^{30}	9.0	8.3	8.3	7.9	7.7	7.3	7.3	put on
April 12. Sun	9^{00}	5.7	5.8	6.0	6.0	6.1	7.1	[1] 22.0	off
	16^{30}							Several dead	
April 13. Sun	9^{00}	5.7	5.7	5.7	5.7	5.7	5.7	all dead	
	17^{00}								
April 14. Sun	11^{30}	6.3	5.1	5.7	5.2	5.0	4.9		
April 15. Sun	9^{30}	[1] 7.7	6.8	6.1	6.2	5.5	5.6		
April 16. Sun	10^{00}	6.4	6.3	6.2	6.2	6.2	6.1		
April 16. Percentage survival:	11^{00}	88	74	51	71	65	67	0	

[1]) The larvae are pale; some dead.

On the 4th of April some larvae about 1 day old (app. no. 30) were taken down to the lobster room and kept there in an iron basin till the afternoon of the 6th, when about 50 larvae were put into each jar. The water of the basin had a specific gravity of 1.0235 at a temperature of 4.5° C., while in the jars the values were 1.022 and 7°. The larvae went at once to the bottom, the difference in temperature and specific gravity being surely felt. The cover was put on at 16.30 hrs.

Looking at the total survival, it will be seen that the jars near the window were then better than the rest, but the resulting percentage is fairly high as far as jar no. 6. In no. 7 all larvae were dead by April 12th, undoubtedly owing to the heat of the »Vitalux« lamp. Other experiments, not described here, have shown that the »Vitalux« lamp 20 cm. away from the aquarium is attractive to the young, so long as the temperature is moderate.

The concentration of the larvae was as might be expected from our earlier experiments.

In jar no. 1 the larvae accumulated to the left, towards the daylight, except at 13.00 p.m. on the 9th of April, when they had moved to the right, especially near the bottom. The light in the jar was on the point of becoming too strong. In this case we have to do with the light coming through the window facing south, on a clear day. Besides the window glass it also passed through the glass wall of the aquarium, about 5 mm. thick, before falling on the larvae. The same phenomenon also occurred in jar no. 2, and in both jars on the 12th also. In jars nos. 6 and 7 the larvae as a rule collected on the right of the jar, towards the diffuse light of the room.

In jar no. 5, however, some alternation occurred; ordinarily the larvae were observed on the window side, but when the artificial light was turned on they moved to the right.

Although these experiments went on for 9 days, the water was not renewed, as was the case in the other experiments also. Preliminary experiments showed that the changing of the water may often prove fatal to the young fish, even if great care be taken. And analysis of the oxygen content showed that it varied but very little from the beginning to the end of the experiments, so long as the larvae were few in relation to the volume of water in the jars.

Table 3 gives the combined results of the experiments described. In the first two the tops of the jars were open to the light; in the next two a roof was placed over the whole box. The »Vitalux« lamp was used in the last two experiments.

Table 3. The percentage of cod larvae surviving.

Experiment	Jar No.: (no. 1 nearest window.)							Duration in days
	1	2	3	4	5	6	7	
No. 9.	0	0	0	4	13	30	23	7
No. 10.	0	0	45	8	31	90	100	4
No. 11.	88	80	78	82	72	84	0	2
No. 12.	88	74	67	71	65	67	0	9

Several other experiments were undertaken, but as the results all agree they will not be dealt with in detail.

B. Cod larvae in waters of different specific gravities.

On the 12th of April 6 jars, each containing 200 cm^3., were filled with sea water of specific gravities from 1.009 to 1.028 at a temperature of 11°. Fifty cod larvae (app. no. 5) with the yolksac nearly resorbed were put into each jar (experiment no. 15), and the jars placed in a laboratory in diffuse light. The particulars are given in table 4. The disposition of the asterisks illustrates the occurrence of the larvae in the different layers, whether near the surface or near the bottom. A cross (†) denotes the occurrence of dead larvae.

After 3 days the larvae in jars nos. 1 and 2 had died, as well as some in jar no. 3. In the remaining jars they were still all alive, from which it seems that water of specific gravity about 1.018 (approximately 22 $^0/_{00}$ saltness) is sufficient for cod larvae in this stage.

The distribution of the larvae is connected with the specific gravity of the water, the larvae generally keeping to the surface where the water is relatively more salt, and to the bottom were it is less so. But it is evident that the active swimming of the larvae may cause exceptions to the rule. It is of interest to note the difference between the distributions at 18.00 hrs. on April 12th and at 9.00 hrs. the next day. In three of the jars, with water of medium saltness, the larvae had moved from the bottom to the top, where they showed a tendency to remain. This may be the result of the larvae getting accustomed to the medium salinities.

In another experiment (no. 14, table 5) two sets of jars were used, one set being kept at optimum temperatures, 3—5° C., while the other was cooled down and kept at temperatures between 0.3 and 0.5° C. (except in one case in which the snow used for cooling had melted, when the temperature rose to 2.9). The experiment was started with eggs in the last stage. In two days nearly all were hatched.

In water of specific gravities 1.025 and 1.021 the larvae were lively at the end of the experiment at both optimum and low temperatures. At specific gravity 1.017, however, the larvae accumulated near the bottom, and in the cold water were motionless. In the jar kept at optimum temperatures, however, they were lively. At this stage of the experiment the larvae kept at optimum temperatures appeared dark in colour (generally a sign of well-being), while the larvae kept at low temperatures were all pale, the chromatophores being contracted.

In water of specific gravity 1.021 the larvae kept at optimum temperatures remained nearer to the surface than the larvae in cold water. This is in accordance with the observations made in the hatchery. After 4 days the jars containing water of specific gravities 1.023, 1.019 and 1.015 were interchanged, the jars from the cold apartment being placed in the temperature and *vice versa*.

Table 4. Experiment 15.

Date	Hour	Temp. ° C.	Specific gravity: 1.009	1.012	1.015	1.018	1.021	1.024	1.028
April 12.	12^{30}	11	*	*	**	*	**	**	**
			*				*	*	*
			**	*	*	*	*	*	*
	13^{00}	10.2	*	*	*	*	*	*	**
				*	*	*	*	*	*
			**	**	**	**	**	*	*
	13^{30}	9.5	*	*	*	*	*	*	**
						*	*	*	*
			**	**	**	**	**	*	*
	16^{00}	8.8			*	*	*	*	**
							*	*	*
			**	**	**	**	**	**	*
	18^{00}	8.5		*	*	*	*	*	**
					*		*	*	
			**	**	**	**	**	**	*
13.	9^{00}	8.5	*	*	**	*	**	**	**
				*	*	**	*	*	*
			**	**	*	*	*	*	*
	16^{30}	8.3		*	*	*	**	**	**
				*	*	*	*	*	*
			†	**	*	*	*	*	*
14.	11^{30}	6.4			*	*	**	**	**
					*	**	*	*	*
			†	†	*	*	*	*	*
15.	13^{00}				**	*	**	**	**
						*	*	*	*
			†	†	†	*	*	*	*
Percentage survival:			0	0	22	100	100	100	100

In jar no. 2, originally kept at low temperatures, the larvae went to the bottom when placed under optimum temperature conditions, but the next day they were again at the surface. In jar no. 8 they left the surface when the temperature was lowered, but in this case they did not rise again.

In the waters of lower specific gravity no changes were observed in this respect, the larvae ordinarily accumulating near the bottom.

In jar no. 12 the larvae were motionless after 6 days, the two last being at low temperatures. The larvae in jar no. 6, at the same specific gravity, recovered when they were transferred from low to optimum temperatures, the coldness of the water during the first days evidently not having injured them.

It is of great interest to note that the larvae kept at low temperatures for the first few days retained their pale colour even after having been transferred to the optimum temperatures for two days.

Table 5. Experiment 14.

Specific gravity:		1.025		1.021		1.017		1.023		1.019		1.015	
Jar no:		1	7	3	9	5	11	2	8	4	10	6	12
Temperature:		low.	opt.	low.	opt.	low.	opt.	low.	opt.	low.	opt.	low.	opt.
Date	Hour												
April 2.	11^{30}	**	**	*	**	*	*	**	**	*	*	*	*
		*	*	*	*			*	*				
		*	*	**	*	**	**	*	*	**	**	**	**
4.	9^{00}	**	**	**	**	*	*	**	**	*	*		*
		*		*				*					
		*		*	*	**	**	*	*	*	**	**	**
5.	12^{00}	**	**	*	**		*	*	**	*	*		
		*	*	*	*			*	*				
		*	*	**	*	**	**	*	*	**	**	**	**
6.	13^{00}	**	**	*	**	*	*	**	**	*	*		
		*	*		*			*	*	*	*		
		*	*	**	*	**	**	*	*	**	**	**	**
								opt.	low.	opt.	low.	opt.	low.
	14^{30}	**	**	*	*		*	*	*	*	*		
		*	*					*		*			
		*	*	**	*	**	**	**	*	**	**	**	**
	16^{10}	*	**		*		*	*	*	*	*		
		*	*					*	*	*	*		
		*	*	**	*	**	**	**	*	**	**	**	**
7.	9^{10}	**	**	*	**		*	**	*	*	*		
		*							*	*	*		
		*	*	**	*	**	**	*	**	**	**	**	**
	13^{30}	*	**		*		*	*	*	*	*		
		*	*						*				
		*	*	**	**	**	**	*	**	**	**	**	**
8.	13^{30}	**	**	*	**		*	**	*	*	*		
		*	*	*	*	*	*	*	*	*	*	*	*
		*	*	**	*	**	**	*	*	*	**	**	**
April 8.	14^{30}												
Final result:													
Vivid		+	+	+	+	−	+	+	+	+	+	+	−
Pale		+		+		+		+		+		+	
Dark			+		+		+		+		+		+

C. On the influence of hydrogen-ion concentration on cod larvae.

On the 14th of April at 16.30 hrs. a set of small aquaria (200 cm^3) was filled with sea water of different degrees of alkalinity.

The sea water used had a temperature of 7.4° and a specific

gravity of 1.0255, or a salinity of approximately 31 ‰. The pH was 7.8.

Using chalk and acetic acid, the following values of pH were prepared.

Jar. no.	8	9	10	11	12
pH	4.1	5.7	6.6	7.8	8.5

Newly hatched larvae were used, taken from app. no. 9 of the hatchery.

In jar no. 8 the larvae at once grew uneasy, and in a few minutes they were motionless, most of them near the bottom, others suspended. The larvae in no. 9 were practically the same as in no. 8, but a few were moving after some minutes.

The larvae in nos. 11 and 12 were quite lively.

After half an hour the situation in jars nos. 8 and 9 was unaltered. In no. 10 the larvae swam about, but did not look quite healthy. Those in nos. 11 and 12 were all well. The next day at 10.30 hrs. all in jar no. 8 were dead. In no. 9, however, the larvae had recovered and were just as lively as in the other jars (nos. 10, 11, 12). The pH in the aquaria had changed quite insignificantly by the end of the experiment, but the temperature was then 8.2°.

It will be seen that the cod larvae are fairly resistant to changes in pH, the critical point apparently lying near pH 5.7.

The next day, April 16th, the experiment was renewed with larvae 2—3 days of age (from the same apparatus as the former experiment). The result was much the same, though the larvae in jar no. 8 continued to swim for about half an hour. They all showed signs of uneasiness, however, and eventually ceased swimming; the activity of the heart was lowered, they turned pale in colour, taking on a somewhat milky appearance, and the skin was often contracted, especially over the second anal pigment.

The larvae in jars nos. 9—12 remained healthy for four days, after which they were transferred to other aquaria.

Summary.

The experiments described on the influence of light on the larval cod confirm the results arrived at by Dannevig (1932). The cod larvae are attracted by moderate light, but die when exposed to strong light.

The experiments with larval cod in waters of different specific gravities show that the larvae survive in water of specific gravity 1.018 (i. e., about 22 ‰ saltness). At specific gravity 1.017 the situation is critical at low temperatures (0.3—0.5°), but at optimum temperatures (3—5°) the larvae are unaffected. Larvae kept at low temperatures for 4 days in water of specific gravity 1.015 (about 18 ‰ saltness) will recover, however, when brought under optimum temperatures. The larvae kept at first at low temperatures are pale, and

keep that appearance even after being transferred to optimum temperatures for two days.

The experiments with cod larvae in waters of different alkalinities showed that newly hatched larvae, probably the most susceptible stage, survived in sea water of pH 5.7, but died at 4.1. When brought into the aquaria, however, it was evident that waters of pH 5.7 and 6.6 were disagreeable to the young fish, though after 24 hours they seemed to have adapted themselves to these conditions. The sea water used was at a temperature of 7.4° C. and a salinity of 31 $^{0}/_{00}$. (No. 9).

Reviews.

Johs. Schmidt. Dana's Togt omkring Jorden, 1928—1930. Gyldendal. København, 1932.

Non cuivis homini contingit adire Corinthum — so we may think of the well-known leader of this expedition and his small band of happy collaborators, to whom fell the grateful task of circumnavigating the globe with a scientific aim in mind — above all, the completion of the world-embracing eel researches. The famous Carlsberg Fund for Scientific Research provided the financial means, and the Danish Government put the "Dana" at the disposal of this expedition, of which men in the foremost scientific rank in Denmark (including the late lamented Prof. Ostenfeld) were the promoters, and to which H. R. H. Prince Valdemar acted as protector. Along with scientific researches, the expedition fulfilled another task, that of re-establishing a link between Danes scattered all over the world with the mother country by personal intercourse and by the occasional showing of a film of Danish enterprise and industry. This national purpose prompted the head of the expedition to publish an account of the voyage in the Danish language.

The "Dana", a former English mine-sweeper of only 360 tons, with such a voyage before her, presented special difficulties in the matter of coaling and stores. She left Copenhagen in June 1928, visited the Mediterranean, crossed the Atlantic and passed through the Panama Canal to the Pacific and Indian Oceans, where her main field of operation lay. All through the voyage plankton catches were made, serial hydrographic observations taken and echo-soundings which revealed a much more variable relief of the ocean bottom than was hitherto assumed; as, e. g., between the Maldives and the Seychelles (fig. 198, p. 255), where not less than 181 soundings were taken as compared with only 12 earlier ones.

Interesting reading as the various chapters written by the members of the staff may provide to the general reader, the student of nature will find additional enjoyment in the wealth of information about oceanography, meteorology and, above all, aspects of marine life. Eel investigations, of course, are constantly referred to and there is a special chapter about such investigations during the period 1905—1930, written by the leader of the expedition himself, in which the life histories of Atlantic and Indian eels are compared. It had previously been stated, as a result of a world tour by Prof. Schmidt in 1926, that the various freshwater eels of the Pacific and Indian Oceans are only to be found in those rivers which face the oceanic depths, and not in those terminating in shallow seas (the most notable example is the island of Java); this fundamental fact has been amply proved during the expedition (see the chapter "Omkring Sumatra"). After leaving the East Indies eel larvae were not found over a large tract, and it was only near the northern point of Madagascar that the larvae of East African species were caught (three of the four species living here). After

visiting the East African coast the "Dana" rounded the Cape of Good Hope and, on her return voyage across the Atlantic, penetrated again into the Mediterranean, where catches of eel larvae corroborated the fact, established by Schmidt before the war, that these larvae in the Leptocephalic stage are older, the more eastwards they are found — a fact explained by these Mediterranean larvae all entering through the Gibraltar passage (their average length being nearly 67 mm. near Gibraltar and 71.5 mm. off Messina). An interesting chart (fig. 262, p. 345) shows that the amounts of nitrate and phosphate at 150 m. depth are much larger out in the Atlantic than in the Mediterranean basin, and in the eastern part of the latter sea they diminish greatly, phosphates even disappearing completely.

The book is fully illustrated by hundreds of fine photographs, mostly taken by members of the expedition. Among these photographs a remarkably fine snapshot of a flying fish in action may be especially mentioned (fig. 114. p. 161, taken by T. C. Roughley). Outstanding representations of the remarkable land animals of New Zealand and Australia are also interesting. The foreign reader may somewhat regret that this book, full of original and fascinating observation, has been written in a language which requires so much exertion of the mind, but this hampering character is explained by the national purpose of furnishing a description of a Danish undertaking for the benefit and understanding of the general Danish public, both at home and abroad.

J. J. T.

G. Wüst, G. Böhnecke und **H. H. F. Meyer.** Ozeanographische Methoden und Instrumente. Wiss. Ergebnisse der Deutschen Atlantischen Expedition 1925—1927, herausgeg. von A. Defant. Band IV, I. Teil. Berlin und Leipzig, 1932.

The standard of accuracy that has for some 30 years distinguished the field work of physical oceanography, was essentially due to Fridtjof Nansen. Thanks to the ingenuity and efforts of Alfred Merz and his fellow workers the German Atlantic Expedition with the "Meteor" represents in this respect further substantial progress. The information and suggestions given in the important volume under review will accordingly have to be duly considered in the preparation of future deep-sea expeditions.

It would be impossible to refer here so all the interesting points, such as the printed forms for recording the work on deck and other matters of organization; description of and experience with new or improved instruments; comprehensive investigations of the Mohr method of chlorine titration, as well as of different materials for the hydrographer's wire rope. (Both steel and aluminium bronze were found to be decidedly preferable to phosphor bronze).

The design of the hydrographer's winch (called in the report *Serienmaschine)* is an important improvement in oceanographical gear. It is driven electrically and seems to have answered every demand as to exact and rapid control over speed in hoisting and lowering. It is a merit of the report that it gives a fairly complete description of the machine, including suggestions for further amendment. Among important improvements in oceanographical apparatus the writer also wishes to bring to notice a type of reversing thermometer of high precision. In order to reduce the parallax errors and with the further purpose of allowing very fine and exact lines of division to be drawn, the fronts of the capillary stems of these thermometers (divided into twentieths of a degree) are ground flat. By these

means and by highclass workmanship, particularly with regard to the place where the mercury thread breaks off, an effective accuracy to within 0.01° was attained under good conditions.

As is well known, E. Ruppin tried in 1906 with some success to determine the depths at which observations were taken, by using simultaneously *two* reversing thermometers, one of them being, as usual, protected from the water-pressure but the other one not. During the "Meteor" expedition wide use was made of his method, and the results are described in an important chapter by G. Wüst on "thermometrical determination of depths". Some 2500 pairs of readings were taken with special precaution so as to give a basis for a study of the errors inherent in the "meter-wheel" values commonly used as expressions for depth. These meter-wheel values can of course be too great but not too small, if the meter-wheel is correct. As a rule the errors did not under favourable circumstances exceed one or two per cent. of the depth, but not uncommonly they amounted to 3 or 4 per cent. or more, even in such cases where the line appeared to be approximately vertical. It appears that a reliable correction cannot be obtained by simply multiplying the meter-wheel value by the cosine of the angle of deviation of the line from the vertical, obviously because this deviation is not necessarily the same at the surface as farther down. The real importance of the matter becomes obvious on examining its influence on the apparent vertical distribution of temperature and salinity. Plotting correct temperatures against erroneous depths will of course be equivalent to a corruption of the temperatures themselves with errors larger or smaller according to the larger or smaller vertical temperature gradient. As is in actual cases exemplified by Dr. Wüst, such indirect errors of temperature may easily come up to one or more tenths of a degree, even in fine weather, and may under unfavourable conditions amount to a degree or more. The following instance is worth quoting: Station 83; 32° S, 25° W; fine weather, light breeze and slight swell; the line at times lay against the ship's side while being lowered but formed with the vertical an angle of 3° only after the messenger was sent down; upper series, reaching down to 1200 m. according to the meter-wheel but to 1155 m. according to thermometrical determination. Proportional corrections were applied to the depths of the intermediate water-bottles, a direct thermometrical determination at 500 m. being rejected as probably false. The consequent negative corrections of temperature at the standard depths of 200, 400, 600, 800, 1000, and 1200 m. were respectively 0.03°, 0.24°, 0.46°, 0.16°, 0.20°, 0.04°, and likewise the corrections of salinity were not altogether insignificant, amounting to — 0.05 at 600 m.

The final conclusion is that the standard of accuracy commonly required in modern oceanography will in most cases not be reached, if the depths are determined in the usual way by means of the meter-wheel; and in future work it will be necessary duly to consider this fact.

V. W. Ekman.

G. Böhnecke, B. Føyn und **H. Wattenberg.** Beiträge zur Ozeanographie des Oberflächenwassers in der Dänemarkstrasse und Irminger See. Ann. d. Hydr. usw. LX Jahrg., H. VIII. Berlin, 1932.

In 1929 the "Institut für Meereskunde an der Universität Berlin" started an oceanographical investigation of the Denmark Strait and Irminger Sea

with the S. S. "Meteor". In July-August 1929, under the leadership of Dr. Böhnecke three sections at right angles to the East Greenland coast-line between 60° and 66° lat. were investigated. In July-August 1930 two new sections between 54°.30′ and 61° N., parallel to the three former ones, and one section along the Reykjanes Ridge were studied. The paper under review, which is the third dealing with these investigations to be published in the "Annalen", gives the results of the chemical and biological investigations of 1930 and a comparison with the results of 1929.

In the area investigated different watermasses meet and mix. The Atlantic water of the Irminger Current runs westwards along the south coast of Iceland, traverses the Reykjanes Ridge and meets the polar water of the East Greenland Polar Current, coming southwards along the East Greenland coast. Where they meet and mix we find the Denmark Strait Polar Front, with sharp gradients of temperature and salinity. South of 60° N. Atlantic water does not pass the Reykjanes Ridge to any considerable extent; between this water and the East Greenland Current we therefore find vast masses of the subarctic mixed waters, with a uniform temperature about 10° C. and a uniform salinity about 34.5 ‰.

The annual cycle of the consumption and regeneration of nutrient salts is well known in the waters of the English Channel and the Norwegian and Murman coasts, and by analogy with the conditions of these waters the authors safely conclude that the investigations in the Denmark Strait were made at the time of the summer minimum of nutrient salts. This accounts for the inconsiderable amounts of nitrates and phosphates in the upper layers of the greater part of the area (5—10 mg. P/m.^{3} and 10—50 mg. N m.^{3}). In Fig. 2 the distribution of phosphates and nitrates in all five sections from the surface to a depth of 100 m. is given. This shows that the upper water layers are found rich in nutrient salts only where the sections traverse the Polar Front, especially in the two southernmost sections IV and V (1930). Here the cyclonal movements along the Polar Front force deep water rich in nutriment to the surface.

The authors direct attention to the interesting fact that the deep water in southern latitudes is richer in nutrient salts than in northern, containing about twice the amount found in northern latitudes, a fact explained by the general water circulation.

The results of the plankton investigations in 1930 are given in the form of graphs (Figs. 3, 4 & 5), followed by a detailed description and a comparison with the results of the previous year.

We give the following summary.

I. The surface layers of the East Greenland Polar Current, with a low temperature and salinity, are separated from the deep water by a pronounced discontinuity layer. This surface layer is poor in nutriment and plankton; only small numbers of diatoms, mostly of the arctic-neritic species, are found.

II. The Atlantic water, however, with a high salinity and temperature, is rich in plankton; 2—400,000 cells per litre of peridinians, coccolithophorides and, to a smaller extent, protozoa and diatoms are to be found. The high consumption has brought the nutrient salts down to low values. In the year 1929, when the investigation was made a fortnight later, the amount of plankton was still greater and the peridinians were markedly predominant.

III. In the mixed waters of the Polar Front the expedition found in both years the maximum amount of nutrient salts, and a large amount of

plankton, — in 1930 the maximum for that year. The lower temperature, about 8° C. on an average (the sharp temperature gradients in this water should be remembered), checks the flourishing of the Atlantic species in the plankton and consequently the consumption; probably the vertical movements, which carry the cells out of the productive layer, have the same effect. Hence the regeneration of nutriment balances the consumption.

IV. The subarctic mixed water is mainly of Atlantic character, containing moderate amounts of plankton and nutriment.

The authors have given excellent synoptical tables and graphs of the results obtained so far and we have every reason to look forward with interest to the full account of these investigations.

Johan T. Ruud.

T. Braarud and **J.T. Ruud.** The "Øst" Expedition to the Denmark Strait 1929. I. Hydrography. Norske Vid.-Akad. Hvalrådets Skr. Nr. 4. Oslo, 1932.

Die Dänemarkstrasse, als die wichtigste Austrittspforte des kalten Wassers aus dem Europäischen Nordmeer in den Atlantischen, ist das Ziel zahlreicher Expeditionen gewesen. Fast allen setzte das starke Treibeis eine Grenze, und so liegen aus dem nördlichen Teil der Strasse nur äusserst wenige Beobachtungen vor. Die beiden Verfasser konnten als Gäste auf dem Robbenfänger "Øst", der für das Fahren im Eis gebaut und durch die Fangtechnik zum möglichst weiten Vordringen in dasselbe genötigt ist, ihre Beobachtungen bis 67°45′ N., 30°29′ W. (Station 34 vom 8. VIII. 1929) ausdehnen.

Ihre Hauptaufgabe waren biologische Untersuchungen, über welche später berichtet wird. Das vorliegende Heft I behandelt die Ergebnisse der nebenher betriebenen hydrographischen Messungen.

Es wurden nördlich 66° N. und westlich 28° W., also zumeist auf dem Schelf, 48 Lotungen mit Tiefen zwischen 137 und 516 m. gewonnen und in einer Tiefenkarte verwertet. Der Schelf ist am breitesten bei der Grönland-Island-Schwelle, wird nach Süden schmaler, hat aber in 66° N. noch eine weit nach E. vorspringende Zunge. Eine submarine Fortsetzung des Kangendlugsuak-Fjords nach S., die schon von Nansen vermutet wurde, konnte bestätigt werden; sie erreicht in ihrem breiten äusseren Teil Tiefen über 500 m.

Bei gelegentlichem Stilliegen des Schiffes wurden 31 Serienmessungen bis zu 1000 m. Tiefe ausgeführt, davon 24 im gleichen Gebiet wie die Lotungen, der Rest auf der Heimreise nach Aalesund; ausserdem zahlreiche Oberflächen-Beobachtungen. Die Ergebnisse — Salzgehalt, Temperatur und Dichte — sind *in extenso* mitgeteilt.

Trotz der durch den Fangbetrieb erzwungenen Zufälligkeit der Stationen konnten dieselben zu drei Schnitten in der Dänemarkstrasse vereinigt werden.

Die Diskussion der Schnitte ergibt, dass der Polar- (Ostgrönland-) Strom, durch die Erdrotation an den Schelfrand gepresst, selten tiefer als 100 m. reicht (Station 18 bis 160 m.), wenn die 0°-Isotherme als Grenze betrachtet wird. Er wird aber durch das Eindringen von schwererem Atlantischen Wasser entlang den Einschnitten in den Schelf, wie z. B. den erwähnten submarinen Fjord, stellenweise verdrängt und bildet dann nur noch eine ganz dünne Schicht.

Obwohl keine Strommessungen ausgeführt wurden, beobachteten die Verfasser die höchsten Geschwindigkeiten am Rande der Küstenbank und in der östlichen Flanke des Polarstromes. Auch auf der Bank selbst wurden mehrfach starke Ströme festgestellt, die aber an den ausgelegten Bojen deutlich als Gezeitenströme erkannt wurden. Die Wirkung der Gezeiten wird übrigens auch fern der Küste an dem Öffnen und Schliessen des Packeises in 12 stündlichem Rhythmus offenbar und verwirrt die Stromverhältnisse. So wurde mehrfach beobachtet, dass die Stromrichtung der oberen Schichten der der unteren entgegengesetzt war.

Die Verfasser unterscheiden neben den drei von Nansen und Helland-Hansen definierten Wasserarten (Polar-, Atlantisches und Arktisches Boden-Wasser) noch zwei Mischtypen: Atlantisches Misch-Wasser mit $S. < 35\,^{0}/_{00}$, welches durch die Energie des Irmingerstromes weit gegen die Küste getrieben wird und, wie erwähnt, stellenweise die Mächtigkeit des Polarwassers verringert, und ferner lokales arktisches Wasser mit Temperaturen zwischen 0° und 2 C. Letzteres liegt auf weiten Flächen der Küstenbank unmittelbar unter dem Polarwasser und würde wohl besser als Grönländisches Schelfwasser bezeichnet.

Auch zu Eis-Beobachtungen bot die dreimonatliche Reise reichlich Gelegenheit. Wenn auch der Wind die Form der Eisgrenze beeinflusst, so wird ihre mittlere Lage doch nur durch die Stromverhältnisse bedingt und fällt mit der Polarfront zusammen. Denn an dieser trifft der nordwärts gerichtete Irmingerstrom auf das südwärts strömende Polarwasser und setzt dem Eistransport nach Süden eine Grenze.

Es ist zu bewundern, welche Fülle von Beobachtungen trotz des äusserst beschränkten Raumes, des zeitweise stürmischen Wetters und trotz des Umstandes gewonnen wurde, dass die eigentliche Aufgabe des Schiffes wissenschaftlicher Arbeit wenig günstig war und auf sie kaum Rücksicht nehmen konnte.

O. v. Schubert.

N. N. Subow, S. W. Brujewicz and **Was. W. Shoulejkin,** with the assistance of **L. F. Rudowitz** and **N. I. Chigirin.** Oceanographical Tables. Commiss. of Agric. of U. S. S. R.; Hydro-Meteor. Cttee. and Oceanog. Inst. Moscow, 1931.

The authors have undoubtedly performed a valuable service in collecting between one set of covers just over a hundred tables of use in oceanographical work. Oceanography, I believe, is commonly considered as including biological work, but these tables are principally for the hydrographer. In this way they differ from the "Tabulae Biologicae" (W. Junk; Berlin, 1927) and also in so far as they are primarily working tables rather than informative summaries, and there is no general descriptive text or charts. Explanations of the uses to which the tables may be put are given, as well as a list of sources from which they may have been drawn. Some of them, so far as I know, are quite new, as, for instance, Table I, giving corrections for reversing-thermometer readings.

The volume would perhaps find its most appropriate place in the library of a research ship's laboratory; it is quite small, and moderately well bound and printed (in Russian and English). One may be inclined to agree with Prof. Wangenheim when he suggests, in the Preface, that the arrangement of the tables, in some respects at least, is perhaps not all that could be desired. It might be easier to find one's way about if the subject grouping were made a little more definite, allowing the volume to be indexed through

at the margins of the pages (after the fashion of Knudsen's Tables). The tables relating to water movements generally seem to be rather scattered, and it would probably make an improvement if tables like 14 and 43, both essentially connected with hydrodynamical calculations, could be drawn closer together.

Roughly speaking, the first 50 tables deal with physical characters (density — and salinity — and thermal, optical, electrical and acoustical properties of sea water); these are followed by chemical tables (salts, gases, hydrogen-ion concentration etc.), and finally there are various conversion and mathematical tables. Natural logarithms might be more usefully included than the common ones. Other miscellaneous tables, like Beaufort's scale of winds, are interspersed.

I am given to understand that the authors would be glad to receive suggestions for improvement and to be advised of any errors that may be found.

J. R. L.

R. Cherubim. Über Verdunstungsmessung auf See. Ann. der Hydrogr. usw., LIX. Jahrg., Heft IX, pp. 325—335. Berlin, 1931.

In his thorough review of methods of determining evaporation from the ocean, Dr. Cherubim begins with the pioneer work of Mohn, 1876—78, and thus includes practically all that has been done in this field. He examines these efforts critically, and on the basis of this experience revises conclusions of earlier workers, Mohn, Lütgens, Schmidt, and Wüst, and presents the new results, using all available data, about 440 separate measurements.

Marvin's equation $V^x = r\ pf\ (w)$ relating the evaporation during 24 hours to meteorological factors is accepted as satisfactory. Here $p = (0.98\ E - e)T$ is the evaporation potential. Thus Dalton's principle is the fundamental basis.

$E = E_w$ = vapour pressure in mm. at the water surface = saturation pressure of the overlying air at the water temperature T_w.

$e = e_a$ = vapour pressure of the air = saturation pressure at the temperature of the dewpoint of the air.

$T = T_u$ = air temperature, absolute; $t = T - 273$.

W = wind velocity in km/hr.

The constant and the wind factor of (w) are to be determined empirically by fitting. According to Cherubim:

$$\frac{Vx}{p} = 0.25\ (1 - 0.53w - 0.01w^2)$$

The technique of determining the evaporation from the ocean involves: (a) the measurements of evaporation from a suitable vessel or evaporimeter on board ship; (b) correction for size of the evaporating vessel; (c) the reduction of meteorological factors in the immediate neigbourhood of the evaporimeter to sea level values; (d) corrections for the effect of the disturbance of the surface of the water in the evaporimeter caused by the vibration of the ship's machinery; (e) correction due to the relative amount of disturbance of the sea surface due to winds.

He concludes that the evaporation from the sea water in the evaporating

vessel can be best determined by the measurement of the change in salinity of the sea water, by chlorine titrations, and recommends the "Normal Vessel" of glass protected against radiation by a lacquered or nickel-plated holder. The surface area = 288 cm.^{2}, the volume = 2400 cm.^{3}. The evaporation in mm. from the vessel equals:

$$h_v = 1.027 \frac{\text{Vol.}}{\text{area}} \cdot \frac{S_2 - S_1}{S_2}$$

where S_1 and S_2 are respectively the initial and final values of the salinity.

The reduction for size of surface may amount to as much as 50 %, but it is difficult to obtain an accurate value corresponding to all of the conditions. He estimates the gradients of the various meteorological factors between the vessel and the sea surface, and with their aid corrects the evaporation from the evaporimeter to that at sea level. The gradients from 9 to 0.2 metres above sea level found by Wüst to average 0.6° in T, 29 % in $\left(100 - \frac{e}{E_a}\right)$, 1.1 mm. = 12 % in e, and 30 % in w have been reasonably well confirmed by later investigations.

For the reduction of Mohn's North Sea measurements, Cherubim adopts as the most probable value of the coefficient .95 × .92 × .80 × .80 × .75 × .70 = .29 where the reduction factors pertain respectively to vibration, condition of the sea, conduction, (E — e), wind, and size of vessel. He finds that estimates of evaporation presented by Lütgens when properly corrected are reduced by about 45 %, and criticizes Schmidt for regarding Lütgens zonal values as relatively correct and applying only a constant factor 0.52 to reduce them to the actual values. The new estimates of the average evaporation during 24 hours for 10° zones are:

V^x for 10° Zones.

Latitude	Atlantic	All Oceans	Latitude	Atlantic	All Oceans
80°—70° N	0.3 mm.	0.3 mm.	0°—10° S	4.3 mm.	3.8 mm.
70°—60° N	0.4 mm.	0.4 mm.	10°—20° S	4.2 mm.	4.0 mm.
60°—50° N	1.3 mm.	1.3 mm.	20°—30° S	3.8 mm.	3.8 mm.
50°—40° N	2.3 mm.	2.3 mm.	30°—40° S	3.0 mm.	3.0 mm.
40°—30° N	3.2 mm.	3.2 mm.	40°—50° S	2.0 mm.	2.0 mm.
30°—20° N	4.2 mm.	3.9 mm.	50°—60° S	0.8 mm.	0.8 mm.
20°—10° N	4.4 mm.	4.0 mm.	60°—70° S	0.3 mm.	0.3 mm.
10°— 0° N	3.2 mm.	3.4 mm.	**Mean**	**2.8 mm.**	**2.9 mm.**

He also estimates that the annual evaporation from the ocean is 371,100 km.^{3} and the annual precipitation is 334,000 km.^{3}, which requires a compensating runoff of 37,100 km.^{3}. The following table summarizes his new results pertaining to all land and water surfaces:

The Water Economy of the Earth.

	Annual	Daily					Annual	Daily
V_m	103 cm.	2.8 mm.	Sea ..	Evaporation	Land .	V_1	50 cm.	1.4 mm.
N_m	93 cm.	2.5 mm.		Precipitation		N_1	75 cm.	2.1 mm.
$F(m)$	10 cm.	0.3 mm.		Runoff		$F(1)$	25 cm.	0.7 mm.

He stresses the need of observations from a stationary ship as a control for improving methods of reduction to true meteorological conditions. While accepting about 8 % as a fair estimate of the increase in evaporation from the vessel due to vibration, he states that special experiments are

needed to determine the effect due to surface disturbance of the sea, and emphasizes the difficulties that this question involves.

Apparently the author has gone about as far as possible in developing and applying methods of reducing vessel evaporation to sea surface with the means employed: empirical formulae in combination with the Dalton evaporation principle and the meager observations available to date. He has rendered a valuable service in presenting the results of such a careful investigation.

It appears that full advantage should be taken of the technique that has been developed for applying the principles of energy transformation to so complex a problem as determining evaporation from the sea. However, Cherubim has barely mentioned the energy methods used by Schmidt, Ångström, Cummings, and others, and has relied entirely upon a different and largely empirical procedure.

Geo. F. McEwen.

W. R. G. Atkins and **H. H. Poole.** A preliminary comparison of the neon lamp and potentiometer methods of submarine photo-electric photometry. Jour. Marine Biol. Assoc. N. S., Vol. XVII, No. 3, pp. 617—631. Plymouth, 1931.

These authors wished to increase the sensitivity of a vacuum photo-electric cell circuit and integrate the variable light intensity under water disturbed by surface waves. For this purpose the neon lamp was placed in the cell circuit and connected in parallel with a condenser. The variable photo-electric current is directly proportional to the variable illumination of the cell exposed beneath the waving surface. The variable current gradually charges the condenser which produces flashes in the neon lamp which serves to integrate the light effect in terms of the number of flashes per unit of time.

In this paper, the percentage of light at the various depths is given in terms of readings just above and just below the surface. This makes the results more usable by biologists than the absorption coefficients formerly used by these writers. The percentage of light lost at the surface is also given and is in general less that that found by Shelford (cited in the article being reviewed). This author used spherical photo-electric cells of large size with the lower third of the sphere surface sensitized. The cells were immersed directly in the water. These cells usually showed greater surface losses than were noted by Atkins and Poole, who have called attention to the concave water lens, produced above the cell. Its actual effect has not been demonstrated, however. It is to be hoped that the various methods used by other authors using photo-electric cells will be compared and standardized at Plymouth. The surface effect should be studied with cells made between parallel glass plates.

Atkins and Poole have made very important contributions to the use of cells on rough waters beneath variable skies and their equipment may well serve as models for work under severe conditions. Their apparatus is, however, all complicated and their cells of forms designed primarily for laboratory use, being of the usual concave type with relatively small apertures admitting light principally from one direction. The cells have been mounted in water-tight cases and covered with diffusing glasses.

V. E. Shelford.

D. C. Gall and **W. R. G. Atkins.** Apparatus for the photo-electric measurement of submarine illumination assembled for the U. S. A. research ship "Atlantis". Jour. Marine Biol Assoc. N. S., Vol. XVII, No. 3, pp. 1017—1027. Plymouth, 1931.

The latest and most refined type of potentiometer and amplifier were constructed along lines already well known to workers in the field. An excellent neon lamp outfit is enclosed in a case and provided with an eyepiece for observing the flashing of the lamp. The reading devices appear ideal but very complicated. This is necessitated by the small current used. The apparatus does not include a direct reading galvanometer.

The photo-electric photometers were three in number — two vacuum cells and one potassium gas-filled cell. Compared with earlier cells these were larger and with larger apertures. They were enclosed in water-tight casings and provided with diffusing glasses above the apertures.

Workers in this field should have some one to make cells suited to their needs. Atkins and his co-workers have, in the past, been supplied with some very poor gas-filled cells. In no case known to the reviewer are cells properly standardized, tested and selected for biological use in sunlight, by makers. The forms are usually suited to use with artificial light, lenses, etc., but not with sunlight.

Hope was expressed in the paper that comparison could be made with the visual observations of Beebe. He went to 433 metres, while the gas-filled cell has a cable reaching only to 200 metres. The equipment consisted of very sensitive measuring apparatus and very weak gas-filled cells. With better cells there is no apparent difficulty in measuring light at 400 to 500, or even 1,000 metres. Shelford and Gail (cited in the paper being reviewed) took readings at 125 metres in Puget Sound with simple cells exposed directly in the water. They had been tested in an hydraulic press before being filled. These could have been used at 200 metres or more. A battery of small cells in heavy glass connected in parallel may be made to give a large current. Such a battery of cells exposed directly in the water with connections insulated with vaseline and the weight carried on the insulated conductor, should make possible effective measurement down to 1,000 metres.

V. E. Shelford.

F. A. Stanbury. The effect of light of different Intensities, reduced selectively and non-selectively, upon the rate of Growth of *Nitzschia Closterium.* Jour. Marine Biol. Assoc. N. S., Vol. XVII, No. 3, pp. 633—653. Plymouth, 1931.

There have been many conflicting reports on the relative effects of wave-length and energy on photosynthesis. This author has gone a long way towards the demonstration of three important facts:

1. There is an optimum light intensity of energy content of white light — too great an intensity tending to retard growth.

2. The amount of energy transmitted is more important than the specific wave-length transmitted.

3. There is chromatic adaptation of the diatoms. They tend to assume colours complimentary to the colour of light to which they were subjected. The diatoms were cultured in Miguel sea water.

V. E. Shelford.

W. von Buddenbrock. Bericht über die in Schilksee bei Kiel in den Jahren 1928—1931 durchgeführten Erbrütungsversuche an Schollen-eiern. Ber. d. deutsch. wiss. Komm. f. Meeresforschung. N. F., Bd. VI. Heft 2. Leipzig, 1932.

Dr. von Buddenbrock in his final report on the hatching of plaice eggs in the Laboratory of the Schilksee near Kiel gives a very interesting account of the experiments which he has been supervising for the last three years. Although these researches have not shown that any increase of young fishes can be expected with the methods employed, the results are valuable, as many difficulties have been overcome and every year the improvement is manifest.

The plaice in this region lives under peculiar conditions, the salinity of the water being so low that it almost reaches the limit which the fish can stand, it being on the borders of its natural distribution. The consequence is that in any hatching experiments the eggs, which naturally float freely on being discharged from the female, in the water of the Schilksee sink to the bottom and it is only by the addition of salt to the water in the containers that they can be brought to the surface. Statistics show that at the very best the number of larvae hatching from the experimental tanks does not exceed what can reasonably be expected from those hatching in their natural surroundings. Besides the disadvantage of the low salinity there were many others, notably that the plaice brought from the breeding grounds had little time to acclimatise themselves to the changed environment and — a very important fact — the growth of bacteria on the egg sheath caused a high mortality in the newly hatched larvae. This last was effectually remedied by the judicious use of a solution of formalin.

The flounder is much more easily reared, an average of 72 % of the experimental eggs being hatched out, which shows that the defective results with regard to the plaice do not arise from technical faults so much as from the susceptibility of that fish.

The feeding of the larvae is a question of importance and Dr. von Buddenbrock has experimented by keeping the newly hatched fishes in filtered water with no food and in water provided with a pure culture of Protococcus. As was to be expected those without food died as soon as the yolk-sac was absorbed, but those fed on the algae lived for some time after the absorbtion of the yolk and evidently ate the algae which were found in quantities in their stomachs. Such a vegetable diet is naturally only suitable for the very young larvae, but the Protococcus certainly appears to be a good food for such early stages, the larvae in the latest experiments being kept for three weeks without great loss of life. The greatest difficulty comes on afterwards when animal food is essential. The author states that even quite young nauplii are too large for such small fishes and that he found when they were fed with natural plankton that they took tintinnids and protozoa. This is not the first time that tintinnids have been found to be the food of young fishes. They are seen frequently inside very young herring which have just begun to feed. Researches resulting in a reliable method for the culture of tintinnids would probably lead to important results. It cannot be long, however, before the larvae would naturally take the smallest crustacea, many of which are not much larger than an average-sized tintinnid, and it is almost certainly among the crustacea that an ideal food will be found on which to rear the young plaice.

M. V. L.

R. Southern and **A. C. Gardiner.** Reports from the Limnological Laboratory II. The Diurnal Migrations of the Crustacea of the Plankton in Lough Derg. Proc. Roy. Irish Acad. Vol. XL, Section B, No. 11, pp. 121—159. Dublin, 1932.

In continuation of their studies on the plankton of Lough Derg, Ireland, the authors have published the results of a continuous series of observations made over a period of six consecutive days on the diurnal migration of the crustacea in water 26.5 m. deep at 6 periods in each 24 hours. Collections were made in an extremely careful manner by serial vertical hauls with a silk closing net at 5 metre intervals, except near the surface where the intervals were reduced to 2 and 3 m. Results are given for the following species:- *Daphnia longispina*, *Bythotrephes longimanus*, *Leptodora kindtii*, *Diaptomus gracillis*, *Eurytemora velox*, and *Cyclops strenuus; Mysis relicta* also occurred in sufficient numbers to be considered. Different types of movement were shown by the different species, and also by the different sexes and ages in a single species. The results shown by each species on consecutive days are not absolutely uniform, there is, however, on the whole sufficient consistency to convey the impression that a true picture has been produced for the behaviour of each species for the time of year and conditions existing when the collections were made, namely August 2nd to 8th, 1922. The authors take into consideration all possible errors, but the consistency of the results would seem to disprove any likelihood of large errors having crept in. Many of the inconsistencies from day to day can be explained by unevenness in horizontal distribution.

In view of the great care taken over these collections this paper must be regarded as a valuable contribution to the study of the vertical distribution of plankton animals in fresh water. The authors made at the same time observations on the temperature, pH and transparency of the water, and on the weather conditions. The weather was fairly consistently overcast and the water turbid (Secchi disc disappeared at 3.8—4.8 m.). The data have therefore additional interest in that they were obtained under markedly different conditions from those of Worthington[1]) on some of the same species in Lake Lucerne in September, when the weather was cloudless and the transparency 8 m.

It is by slowly amassing reliable data of this kind that eventually we shall be able to piece together a true picture of the lives of these plankton animals and explain the differences in their behaviour from time to time and place to place. But, as the authors point out, the collections must be very complete and cover all seasons of the year, and the material thus gained must be subjected to minute analysis as to age, maturity, and sex of any one species.

Interesting notes are also given in this paper indicating that trout and pollan may migrate to the surface at night while perch do not.

F. S. R.

F. S. Russell. On the Biology of Sagitta. Pts. I and II. Jour. Mar. Biol. Assoc. N. S., Vol. XVIII, No. 1. Plymouth, 1932.

Since it has been discovered that British waters are liable to the visits of two species of Sagitta in relatively large numbers further investigations

[1]) Worthington, E. B. (1931). Vertical Movements of fresh-water Macroplankton. Internat. Rev. d. g. Hydr. u. Hydr., Bd. 25, Heft 5/6, p. 394.

are required to determine the factors which influence their distribution. One of these, *Sagitta elegans*, is common and is seldom absent. The other is *Sagitta setosa* and as it has proved to be often rare or absent a record of its visits is of importance for the indication it affords of fluctuating changes in currents. It is very gratifying therefore that Mr. Russell has taken up the study of the subject. He has found the two species in the Plymouth region of the Channel and he has submitted them to a minute analysis with reference to numbers, size and maturity. It is of interest to observe in the light of the work done on the Northumberland coast that in the Channel *S. setosa* was rare until September 1930 and that with marked variations in numbers it prevailed for a year, reaching significant numbers in September 1931.

The hauls were all made at one station, just east of the Eddystone lighthouse, and while this is an advantage it is also a disadvantage for it is as natural as it is misleading to describe the successive events as if they referred to the same population. In such a case as that analysed by Mr. Russell it is important to remember that the diagrams and numbers refer to a succession of different populations. Nevertheless at one station the observations from month to month adequately picture the movements of the plankton as a whole. During the year both species exhibited a gradual reduction in size. For example, *S. elegans* indicated this from May to November, the size increasing again in December and notably in March, smaller examples being prevalent again from June to September of the following year. This feature was met with in the Northumberland coastal region and it was explained as being due to a general transnatation, an offshore migration of the immature and an inshore migration of the mature.

It is interesting also to note that large specimens of *S. elegans* occur apparently regularly in March to May and these are mature. They are accompanied by and succeeded by a race of smaller sized spawners. There is in fact some indication of a similar succession in the case of *S. setosa*. The observations point to a single spawning season of long duration from about January to September. This is different from what has been found on the east coast, where a spring and autumn spawning seemed to be regular. Such points will be cleared up by fresh work. It is to be hoped that other workers will follow the excellent example of Mr. Russell, for, as has been said, the rare visits of *S. setosa* if they are sufficiently investigated are bound to throw a welcome light upon current distribution and even upon the fluctuations of Fisheries.

A. M.

O. Pratje. Die Sedimente der Deutschen Bucht. Eine regional-statistische Untersuchung. Wissensch. Meeresunters., N. F., Abt. Helgoland, Bd. XVIII, H. 2, Abt. 6. Kiel u. Leipzig, 1931.

This elaborate monograph (126 pages with 14 tables and 26 illustrations) is a work of first-rate importance, not only because of the great mass of information presented concerning the bottom deposits of the area dealt with (that part of the North Sea east of 5° E. which is south of 55½° N.) but because of the ever-present idea that the results of such a research must have an intimate bearing upon certain thorny problems ever confronting the palaeontologist. The English reader will, in this connection, recall the great importance attached by Gertrude Elles (Brit. Assoc. 1923) to Petersen's work, and Professor Pratje's paper could very profitably be studied

by all whose task it is to interpret fossil sediments and to select or use zonal fossils. The author, who promises further similar publications devoted to other parts of the North Sea, benefited greatly by enthusiastic support and assistance from many sources. The opening account of earlier relevant work contains an expression of surprise that there exists for the North Sea, "das so nahe vor unseren Toren liegt und immer wieder als Beispiel in der Geologie benutzt wird", no really systematic statistical study of bottom deposits. Borley's well-known work is much quoted, but his finer fractions are regarded as having been of too wide range; Pratje's are so "narrow" as to permit the labelling of the finer samples in such strict numerical fashion, that personal impressions are ruled out in making comparisons. The author who has been systematically collecting bottom-deposit samples since 1921 from all over the North Sea, but who has at present ample enough material only from the German Bight, here deals with material resulting largely from Petersen grab sampling — though other apparatus has contributed. Accounts follow dealing with lime-content, humus, colour, clay, fine mud, grain-size distribution, degree of rounding, quartzless sediments, quartz sand, coal, clinker, peat, etc. A collaborator furnishes a pollen-analysis of the latter. Full attention is devoted to the organic content of the bottom samples. The spatial distribution of the various deposits is related in detail to the currents and tidal streams, and an interesting finding is that an area where a current convergence exists, is filled with very fine material. The Wendicke-Böhnecke conceptions of the German Bight currents must, we are told, represent the prevailing conditions, since the deposits so closely accord in their distribution with what the currents can be conceived to have brought about. The fine mud areas are studied in detail and river-transported material receives due attention. With Zorell (Ann. der Hyd. usw. of April 1932) one realises the probable profit in assessing the importance of the river water — salt water contact in this connection, which would result from a study of the muds further into the Elbe. Pratje is able to compare certain present-day samples with others taken from the same places 20 years ago; the "stability" discovered does not surprise him in view of the agencies (current and tidal streams) held to be responsible for the distribution. The residual currents of the area are indicated (amongst other ways) by the distribution of non-quartz minerals which, on the disintegration of their parent rock fragments, have been carried ahead by the currents.

A research which, like this, will materially assist the Stratigrapher in learning "wie man aus fossilen Sedimenten und ihrem Inhalt zu den damaligen Umweltverhältnissen kommen kann" is a very welcome addition to lithological literature. The paper contains a full bibliography, but the absence of numbering against the meridians and parallels on all the illustrative charts, save one, is very irritating.

J. N. Carruthers.

A. C. Stephen. Notes on the Biology of Certain Lamellibranchs on the Scottish Coasts. Journ. Mar. Biol. Assoc. N. S., Vol. XVII, No. 2, pp. 277—300. Plymouth 1931.

In this work the author continues his series of papers on the biology of shore Lamellibranchs. He makes a number of valuable additions to the knowledge of the biology of *Cardium edule, Tellina tenuis* and *Macoma baltica,* as a result of careful examinations, measurements and countings of

winter rings of a large number of individuals, collected at different times of the year and in different places on the Scottish coast.

(a) *Cardium edule.*

The observations were carried out on the Hunterston Sands on the Ayshire coast in 1929 and 1930. In contradistinction to Johnstone and Orton the author found that breeding takes place in summer, the spat appearing on the sands in the beginning of August. Of the spat some few individuals reach a size of 10 mm. before winter, but most are under 6 mm. The first winter ring laid down by these small shells are usually visible in specimens up to one or two years of age, but in older shells the ring is often quite obliterated. The first of the several well-defined rings is therefore not the first, but the second winter ring, and the author thinks that Orton in his Plymouth cockles has overlooked the first winter ring, and that his experiments were not suitable to study the spat-fall.

»False« or »disturbance rings« were not found in any quantity in the Millport cockles, and a study of the number of winter rings showed that certain year-groups predominated, the 1926 spat being the dominant at all stations. Very few cockles, spatted in 1925 and previous years, were found.

The author suggests that the mortality is heaviest amongst the slower growing individuals, as the mean lengths of the winter rings tend to be higher in the older year-groups than in the younger groups.

The size of the cockles increases regularly from H. W. M. to L. W. M., due to an increased rate of growth.

(b) *Tellina tenuis.*

The author's earlier observations regarding this species in Kames Bay have been supplemented by observations on the annual spat-fall at one station in the same bay. The rich 1926 year-group remained the dominant group until the summer of 1930, when, after spatting, they largely died out. Also the spat of 1930 was abundant.

The mortality was found to be comparatively light amongst the spat during winter but might be exceedingly heavy after spatting amongst the adult population. The preponderance of a year-group appeared to depend not only on a rich spat-fall, but also on a good start in growth.

(c) *Macoma baltica.*

Observations of this species were carried out in Aberlady Bay in the Firth of Forth during the years 1929 and 1930. The breeding period is apparently in spring, April to May; small individuals appear in June. By the end of the first year the average size is about 5 mm. and by the end of the second 8—9 mm. The end of the breeding season in the third summer seems to mark the termination of the life of the average individual.

H. Blegvad.

G. Gilson. Recherches sur la Biologie du Hareng »Guai« et sur sa Pêcherie entre Ostende et le Cap Gris-Nez en 1930—1931. Ann. de l'Inst. d'Etudes maritimes d'Ostende. Mém. No. 1. Lierre, 1931.

The term »guai« as applied to the herrings which are caught along the Belgian coast in the winter of each year signifies »spent«, and was used in the dialect of the Boulonnais fishermen some centuries ago. It is with the several aspects of this spent herring fishery that this latest work of Professor Gilson deals, and the details of the study, the industry of the author and the usefulness of the volume are further magnified, when it is realised that assistance from outside sources was practically nonexistent.

The fishery takes place approximately between the third week of December and finishes at the beginning of March, and this period has been sub-divided into four parts for the purpose of comparing the various components of the fishery, and for observing the changes which occur in the shoals during the season.

At the beginning of the season, the length curves shew that there are two modal groups of fish, the larger herrings predominating, while during the second half the influx of smaller fish is clearly shewn. The study of the age of the fish by means of the scales confirms this change, for during the last two periods the most important age-groups are those of three and four. Accompanying these variations in age and size, it is also noticeable that the character of the vertebral distribution also undergoes a change, for, as the number of young fish increases, so does the number of fish with high numbers of vertebrae.

The author considers that it is most likely that the concentration of spent herrings along this particular length of coast is dependent on the influx of fish from the west, i. e. the Channel, because of the prevailing flow of water from west to east through the Straits of Dover, but should these conditions vary, it would be expected that herrings from the southern North Sea would influence the catches.

It is unfortunate that the growth calculations have not been carried out in greater detail, for by finding the mean values of l_1, l_2, etc., the author cannot arrive at any definite conclusion regarding the growth of the herrings of this area, nor can any adequate comparison be made with fish of other areas. When it is realised that each age-group may produce an l_1 distribution which is complex, it follows that the mean of several age-groups will give a value, which has but little biological significance. It must, nevertheless, be admitted that this initial study of the spent herings will fill an important gap in the researches on the fisheries of the southern North Sea, and the very comprehensive bibliography — 163 books and papers — should be of inestimable value to those who follow on with this work.

Professor Gilson's aim is to establish an Information Bureau for the coastal fisheries of Belgium and northern France, and with the assistance of local industrial bodies, he would like to carry out experimental surveys of the fishery and circulate the results of these surveys to the boat-owners concerned.

W. C. H.

H. Heldt. Le Thon Rouge et sa Pêche. Cons. Int. pour l'Explor. Scient. de la Mer Méditerranée. Rapp. et Proc.-Verb. Vol. VI, Paris, 1931.

Le travail que nous analysons ici est le 6e rapport que l'auteur consacre, dans les »Rapports et Procès-Verbaux de la Commission internationale de la Méditerranée«, au thon rouge (*Thunnus thynnus* L.) et à sa pêche. Il s'agit d'une mise au point exacte de nos connaissances nouvelles sur la question. Les travaux que l'auteur passe en revue portent sur les années 1929, 1930 et, en partie, sur ceux de 1931. Des précisions sont fournies sur la position systématique et la taxonomie de l'espèce et l'on note que l'emploi de la méthode biométrique fait apparaître certaines dissemblances entre le thon tunisien et le thon de l'Algarve. Ces données doivent être multipliées avant qu'on puisse en déduire l'existence de races locales dont la connaissance serait si précieuse pour l'étude des migrations. Car cette question est toujours en suspens et Sella ajoute de nouveaux arguments, dont aucun n'est encore décisif, en faveur d'un voyage transocéanique du thon rouge. Il semble, d'ailleurs, que l'époque de ponte est la même pour le thon

américain que pour celui de la Méditerranée et que leur croissance est identique dans les deux premières années; mais on sait que la taille et le poids des thons américains dépassent de beaucoup ceux des thons d'Europe.

Dans un chapitre spécial l'auteur reprend et complète l'exposé de Sella sur les méthodes de pêche à la ligne employées sur les diverses côtes d'Atlantique et de Méditerranée, et il indique, en outre, la pratique des différentes pêches au filet, la pêche par électrocution et les méthodes en usage sur les côtes californiennes. A propos du traitement des sous-produits, Heldt signale un important progrès à réaliser relatif à l'extraction de l'huile de foie de thon.

L'auteur conclut en montrant que l'étude de la biologie du thon est d'ordre international et qu'elle requiert le concours de savants de tous les pays. C'est pourquoi, nous devons espérer grandement dans les travaux de la commission spéciale d'experts désignée par le Conseil International pour l'Exploration de la Mer et qui s'est réunie pour la première fois l'an dernier à Cadix.

Notons enfin que l'auteur donne de la question une bibliographie complète jusqu'en 1930.

L. Fage.

P. Jespersen. On the Food of the Herring in Icelandic Waters. Medd. fra Komm. for Danmarks Fiskeri- og Havundersøgelser. Ser. Plankton, Bd. II, Nr. 3. København, 1932.

Dr. Jespersen has examined the stomachs of thousands of adult herrings from both purse seine and drift nets. Those caught with the purse seine were from the whole of the northern coast of Iceland and from the fjords indenting the coasts from Huna Bay to Langanes, and the bulk of the drift-net fish came from open sea from off Siglufjord to off Skjalfandi Bay, from 5 to 30 miles out, a few from further out still and a few from the fjords. Most of these herrings examined were collected during the time of the great herring fishery of Iceland which begins at the end of June and ends in the latter half of August or even into September, and were taken in 1927, 1930 and 1931. From 10 to 20 herring stomachs from each catch were put freshly caught into a separate bag and preserved in formalin. The volume of the contents of each stomach was measured by settlement and the relative quantity of the various organisms contained therein estimated, the object being to find in a rough way the most important food.

The average volume of food was ascertained in the herrings from both nets, far more being found in the purse-seine fish than in those from the drift nets. 1930 showed the largest average amount of food, 1931 the smallest. In the large number of purse-seine herrings, not one was found without food, whereas the drift-net herrings were frequently empty. There is more food in the latter in June, the autumn herrings being often very lean. It was found that even if they were caught in the same water the seine-net herrings had far more food in them. This is probably because the two nets fish in different layers of water, the purse seine principally in the surface layers where there is much more food in summer, the drift net in the deeper water where the food is scarcer. The herrings which are in Northern Iceland in summer only come and stay to feed, for they spawn in the warmer waters along the southern and western coasts.

The largest stomach-contents agree with the largest herring catches when there is probably the largest amount of plankton.

The nature and composition of the food was investigated and the

percentages of herrings from each net feeding on certain important organisms ascertained. Here it was found that the purse-seine herrings were almost all feeding on copepods, next in importance being euphausiids. Amphipods, crab larvae and pteropods are eaten to a certain extent. Not so many of the drift-net herrings were eating copepods, although they fed on them largely at times besides the other animals mentioned. Other decapod larvae, cirripede larvae, cladocerans, gastropods, polychaetes, chaetognaths, fish and fish eggs were of minor importance, although occasionally many crab larvae were eaten (*Hyas coarctatus*) and fish (*Ammodytes*). *Calanus finmarchicus* is much the most important food and in the waters north of Iceland it occurs in enormous abundance, colouring the waters red in the summer. It constitutes at least 95 % of the copepods eaten. Very occasionally *Temora longicornis* predominates. Others are *Calanus hyperboreus, Metridia longa, Pseudocalanus elongatus, Microcalanus pygmaeus, Acartia longiremis* and *Oithona similis*. Many were in different stages of development, even nauplii being present.

Euphausiids come next in importance, especially the adults in the drift-net herrings, the young stages which inhabit the surface layers being found in those from the seine nets. *Meganyctiphanes norvegica, Rhoda inermis, Rhoda raschii* and *Thysanoessa longicaudata* all being eaten.

The pteropods *Limacina retroversa* and *Limacina helicina* are occasionally abundant in the drift-net herrings.

This research gives a good idea of the food of these herrings and is an important and valuable contribution to the knowledge of their biology.

M. V. L.

E. M. Poulsen. On the spawning places of the herring in certain parts of the North Sea, the Skagerak and the Kattegat in the autumn of 1930 and some earlier years. Medd. fra Komm. for Dan. Fiskeri- og Havunders., Ser. Fiskeri, Bd. IX, Nr. 4. København, 1932.

Die Arbeit behandelt in erster Linie die Ergebnisse einer Fahrt der »Dana« vom 23. IX. — 31. X. 1930. *Untersuchungsgebiete:* Mittlere Nordsee zwischen der schottischen und nordenglischen Küste einerseits und der dänischen Küste andrerseits, einschliesslich der Doggerbank, ferner der südliche Teil des Skageraks und das Kattegat. Insgesamt 71 Stationen. *Aufgabe:* Untersuchung der Lage und Bedeutung der Laichplätze des herbstlaichenden Herings durch Bestimmung der Häufigkeit und Verbreitung der jungen Larven. *Methoden:* Ringtrawl (Öffnung 2 m. Durchmesser) horizontal 30 Min., meistens in der Tiefe, z. T. auch Stufenfänge. Hensen-Netz (Öffnung $^1/_3$ q.m.) vertikal. Messung der Larven gleich nach dem Fang (unkonserviert). Bei der Behandlung der Ergebnisse werden die kleinen Larven unter 10 mm. Länge von den grösseren über 10 mm. unterschieden. Hydrographische Beobachtungen an den Stationen.

Nordsee (einschl. Skagerak).

1). Vor der schottischen und nordenglischen Küste etwa von Peterhead bis Longstone (10.—16. X: 7 Stationen). Kleine Larven nur spärlich und nur nahe der Küste vorhanden, wo die Bevölkerung im allgemeinen nicht nur jünger war (mittlere Längen 11.6—12.9 mm.) als weiter draussen zwischen 1° W. und 0° (mittlere Längen 16.6 und 19.4 mm.), sondern auch zahlreicher. Die draussen gefischten Larven werden daher als Abkömmlinge von den in Küstennähe gelegenen Laichplätzen angesehen. Auf der küstenfernsten Station im Norden (125 Sm. östlich Peterhead) wurden keine Larven

angetroffen. — Maximallänge der Larven 26 mm. Maximalzahl: Im 30 Min. Ringtrawlfang 253 Stck. (7 Sm. von Longstone); im Hensen Netz pro q.m. 3 Stck.).

2). Doggerbank und Rand derselben zwischen 1° O. und 5° O. (18.—21. X. 15 Stationen). In diesem Gebiet, wo das Laichen später stattfindet als im vorigen, hatte das Ausschlüpfen erst kürzlich begonnen. Die mittleren Längen der z. T. noch mit Dottersack versehenen Larven lagen an den verschiedenen Stationen zwischen 8.2 und 9.1 mm. Das Vorkommen beschränkte sich auf den südlichen Teil der Bank und das Outer Silver Pit und hatte seine östliche Grenze bereits bei 4° O., so dass eine Verfrachtung durch den östlich gerichteten Strom gegen die dänische Küste noch nicht begonnen hatte. — Auffälligerweise wurden keine Larven gefangen über den nordwestlichen Teil des Dogger. Das Dogger-Laichgebiet ist von dem zu 1). besprochenen getrennt, nach des Verf. Ansicht infolge Vordringens kälteren Wassers aus NO. in Richtung auf die englische Küste in der Gegend von Shields; so fand die »Dana« auch jetzt an den larvenlosen Stationen über dem nordwestlichen Teil des Doggers etwas kälteres Bodenwasser als über dem südlichen Teil, wo die Larven vorkamen. — Maximallänge der Larven 16 mm. Maximalzahl: Im 30 Min. Ringtrawlfang 745 Stck. (Outer Silver Pit); Im Hensen Netz pro q.m. 21 Stck.

3). Zwischen 5° O. und der dänischen Küste einschl. des südlichen Teils des Skageraks (25. IX.—8. X. und 21. X.—29. X: 38 Stationen). Hier handelte es sich um weitere Klärung der wichtigen Frage, ob der im Herbst ins Skagerak eindringende ausgelaichte Bankhering der Nordsee, auf dem die grosse Winterfischerei (Dez.—März) im südöstlichen Skagerak und vor der Bohuslän-Küste beruht, sein Laichgeschäft im Wesentlichen bereits in der westlichen Nordsee (z. B. Dogger) erledigt hat oder ob ein erhebliches Laichen ausserdem noch stattfindet auf den vor dem Eingang ins Skagerak gelegenen Bänken (insbesondere Gegend der Kleinen Fischerbank und Jütlandbank). Bekanntlich ist dies i. J. 1903 der Fall gewesen. Seit 1922 sind hier dänischerseits in mehreren Jahren diesbezügliche Untersuchungen ausgeführt worden. Hierbei wurden gelegentlich einige wenige Larven unter 10 mm. Länge gefangen (1922, 25 und 26). In anderen Jahren fanden Fischer Laich in Schellfischmägen oder an ihren Fischereigeräten, so 1928 und 29, aber auch 1930. In diesem Jahre wurden ausserdem nahe der Küste zwischen Hanstholm und Thyboröen einige reife Heringe gefangen. In allen Fällen hat es sich aber seit 1922 nur um sehr geringe Mengen gehandelt, und die »Dana« fing 1930 in dem ganzen, mit vielen Stationen bedeckten Gebiet zwischen 4° O. und der dänischen Küste von Skagen bis Esbjerg keine einzige Larve. Somit zeigt sich, dass die fragliche Gegend für das Herbstlaichen normalerweise nur eine ganz geringe Bedeutung hat. Das starke Laichen von 1903 hat Johansen mit dem in diesem Jahre abnorm starken Einstrom starksalzigen Wassers in die mittleren Wasserlagen des Skageraks erklärt. In dieser Verbindung erwähnt der Verfasser, dass noch andere Faktoren als der Salzgehalt in Betracht kommen müssen, denn auch 1930 war dieser hier erheblich höher als normal (vgl. auch Kattegat), ohne dass ein starkes Laichen stattfand.

Kattegat.

23. IX, 2 Stationen, noch keine Larven vorhanden; zahlreiche dagegen 30. u. 31. X. auf allen 9 Stationen. Diese Larven gehören dem »Kobbergrund«-Hering (Johansen) an, einer herbstlaichenden Rasse (Laichplätze O. v. Kobbergrund, Groves Flak und Fladen), die den grössten Teil des Fanges der in den Herbstmonaten östlich von Læsö und hinab bis Anholt

betriebenen Fischerei liefert. Die Laichverhältnisse sind seit 1922 in mehreren Jahren untersucht worden. Verf. zeigt, dass das Hauptlaichrevier in manchen Jahren weit nördlich (bei Læsö Trindel), in anderen erheblich weiter südlich (Nähe von Anholt) liegt, und die Lage abhängig ist von der Stärke des Einstroms salzreichen Wassers in der Tiefe. Ist er besonders gering (z. B. 1926), so liegt es im Norden, ist er besonders stark (z. B. 1930), so liegt es im Süden. — Maximalzahl (in der Nähe des Hauptlaichreviers bei Anholt): Im 30 Min. Ringtrawlfang 898 Stck; Hensen Netz pro q.m. 36 Stck. Hier auch die kleinsten Larven von 5 mm. Länge an (Mittel 9.2 mm.); die grössten am Nordausgang des Kattegats (Mittel 13.6 mm.) Maximale Länge 21 mm.

W. Mielck.

C. H. O'Donoghue and **E. M. Boyd.** A second Investigation of the Food of the Sea Trout (*Salmo trutta*). Fisheries, Scotland, Salmon Fish., 1932, No. II. Edinburgh, 1932.

The investigations recorded in this paper form a continuation of work of which the authors have previously published an account (Fisheries, Scotland, Salmon Fish., 1930 No. III) and include the examination of a larger number of specimens. The fish were obtained from estuaries, and in various specimens food material from the open sea, brackish water, and fresh water could be recognised. There appears to be no doubt therefore that sea trout, unlike salmon, feed freely in fresh water, and, from the authors' results, it appears that trout living near the upper end of an estuary pass to and fro from brackish to fresh water and feed indiscriminately in either. The nature of the food was found to be substantially the same as that given in the previous paper. In the sea, fishes, chiefly *Clupea harengus, C. sprattus* and *Ammodytes tobianus,* and Crustacea *(Corophium volutator, Neomysis vulgaris* and *Schistomysis spiritus*) formed the greater part of the food while in fresh water they take insects living in the water (larvae of *Trichoptera, Ephemeroptera* and *Plecoptera*) and any that happen to fall on the surface of the water, e. g. *Stenobothrus sp.* and *Saturnia pavonica.* Their food in fresh water is very similar to that of the non-migratory race of the species, the brown trout. The authors rightly point out that however freely sea trout feed a large number of freshwater organisms does not provide the same amount of food as, say, one *Ammodytes,* and the abundant sea food is naturally more favourable to the growth of the fish, as had been previously recognised from the rate of growth deduced from scale readings, than large quantities of smaller organisms obtained with greater difficulty in fresh water.

The authors have continued their investigations into the number of pyloric caeca and the weight of the fish and conclude that there is no relation between them. The relation between the weight and the length of the fish examined is apparently very close though it would have been more clearly brought out graphically had the weight been plotted directly against the length instead of each factor being plotted against the serial number of the fish.

There are also interesting notes on the sex ratio and a very full account of the parasites of the fish examined. The data obtained are given in a somewhat formidable table at the end of the paper, but the results are very clearly and readably described in the text.

In their concluding paragraph the authors renew their appeal for material, and we can therefore look forward to more papers on the problems of

the food of migatory trout, work which, besides being of great ecological interest, is of definite economic importance.

F. T. K. Pentelow.

J. H. Orton assisted by **H. Mabel Lewis.** On the Effect of the Severe Winter of 1928—1929 on the Oyster Drills with a Record of Five Years Observations on Sea-Temperature on the Oyster-Beds of the Blackwater Estuary. Journ. Mar. Biol. Assoc. N. S., Vol. XVII, No. 2, pp 301—313. Plymouth 1931.

Several papers have already been published on the effect of the unusually cold winter of 1928—29 upon the marine fauna both in the North Sea and in the Danish and Norwegian inshore waters. In the paper under review Dr. Orton describes the effect of this extreme cold upon the three species, *Murex erinaceus, Purpura lapillus* and *Urosalpinx cinerea* on the oyster beds in the region of the River Blackwater, Essex.

Mean monthly temperatures of the sea on the oyster beds during the years 1925—1930 are given; they show for January, February and March, 1929, temperatures 4° to 10 ° F. below normal; for one day in mid-February 1929 ice was reported.

The material of the three species named was collected by dredgings; quantitative hauls were not made. The following percentages of the living animals were obtained:

	Urosalpinx	*Murex*	*Purpurea*	Total
1928.....	*7.8* %	*41.2* %	*51.0* %	1,739
1929.....	*71.2* -	*0.2* -	*28.6* -	584
1930.....	*77.9* -	*0.11* -	*22.0* -	5,467

Thus *Murex* was almost eliminated from the beds, and *Purpurea* most probably also became far less abundant, while *Urosalpinx* apparently increased in abundance; this is undoubtedly an indication of the greater capacity of the last named species to resist extreme cold. As *Urosalpinx* is known to be a voracious feeder on young oysters, the economic difficulties of prosecuting oyster culture on the Blackwater beds — already made difficult by the multiplication of the American slipper-limpet *Crepidula fornicata* — have been seriously increased. There was no evidence of unusual mortality among *Crepidula.*

The local fishermen reported that tingle as a whole were less abundant in 1930 than formerly.

Echinus miliaris is also reported to have been killed off during the winter on the shallower inshore grounds on the oyster beds of Whitstable.

The author concludes his paper with some considerations on the problem of natural selection.

H. Blegvad.

G. J. Spencer. The Commercial Crab, *Cancer magister* Dana, in Clayoquot Sound, Vancouver Island. Biological Board of Canada. Bull. No. XXX. Ottawa, 1932.

This paper, which deals with the commercial crab of the Pacific Coast of North America, is one of a »series of bulletins ..... designed for the presentation in non-technical form of subjects of interest to the general public, in particular that related to the fishing industry«. The investigation,

the results of which are dealt with in the paper, was undertaken in order to obtain data on the life-history and ecology of this species, and to determine the adequacy of the regulations in regard to its conservation. The work was carried out in Clayoquot Sound, on the west coast of Vancouver Island, British Columbia, in which the commercial crab is abundant and is fished to a limited extent. The question of marketing the crabs is stated to be a main issue if the fishery in this region is to be developed. A considerable amount of space is devoted to the life-history and habits of this form. A number of half-tone illustrations are included in the text. This is an excellent paper, and the information which it contains should prove of considerable value in connection with the development of the crab fishery and its conservation.

F. S. W.

S. Mužinić. Der Rhythmus der Nahrungsaufnahme beim Hering. Berichte der Deutschen wiss. Komm. für Meeresforschung. N. F., Bd. VI, Heft 1. Leipzig, 1931.

This short paper describes the results of the analyses of the stomachs of 500 trawled herring collected by Lissner in late September and October, 1924, from Brucey's Garden and the Fladen Ground.

As the material was collected at different times of the day and night it was possible to chart the average stomach contents in c.cm. per hour and per herring.

The results obtained harmonise with Lissner's (1925) provisional conclusions that the fully ripe autumn herring are confined in their feeding to certain periods of the day, so that they begin to eat in the afternoon when the light begins to fade, and cease eating towards dawn, while no feeding takes place during the brightest hours of the day.

Muzinic, however, finds that the feeding time is not continuous, but falls into two periods, the principal one occurring from about 5.0 p.m. to 9.0 p.m., after which feeding slackens until about 4.0 or 5.0 a.m., when there is another, smaller rise in the feeding curve. Very little food was found in the stomachs at midnight. There was no period of the day when feeding ceased entirely, because completely empty stomachs were never found in all the herring taken at one particular time.

These results are of considerable interest, and it is hoped that more work will be done on these lines. Unfortunately, the herrings are not feeding briskly in late September and October, so that it is by no means certain that similar results would be obtained at the height of the feeding season in May and June, when the hours of darkness are few.

R. E. S.

H. Blegvad. Investigations of the Bottom Fauna at Outfalls of Drains in the Sound.

A. J. C. Jensen. Hydrographical Investigations of the Pollution of the Sound at Copenhagen. Rep. Dan. Biolog. Station. XXXVII, 1932. Copenhagen, 1932.

At the request of the Office of the Commissioner of Public Works, the Danish Biological Station investigated the effect of the sewer outfalls of Copenhagen and district on the water of the Sound.

The investigation covered a period of six days in May and one in September, 1931. H. Blegvad records the biological results, and A. J. C.

Jensen the hydrographical conditions, as determined by estimations of salinity and dissolved oxygen concentration and temperature readings.

I. The bottom fauna around the sewer outfalls was sampled at 71 stations by means of a 0.1 sq.m. Petersen grab and, as a check on the method, 18 stations were sampled by a diver who dug out 0.1 sq.m. to a depth of 4.5 cm. — a depth similar to that worked by a Petersen grab.

A small-scale map shows the whole of the district and the general distribution of the sampling stations, whilst on three larger scale charts are given the numbers of the stations and the rough weight of animals per 0.1 sq.m.

Small sewers, such as the Sundby District III and the Strandmøllen outfalls, were found to have no effect on the bottom fauna.

Of the larger outfalls those at Klampenborg and Taarbæk had, near the mouth, a small area of fetid mud on which *Mytilus edulis* was growing abundantly. Two of the sewers north of Tuborg Harbour had made a small area of bottom, about 100 metres in diameter, uninhabitable to bottom-living animals, and a »dead« zone could thus be marked out. At the mouth of the Tuborg Harbour sewer, in addition to a »dead« area of about 100 metres diameter, there was also a zone of fetid mud with a rich fauna of bivalves and gasteropods. Outside the dead areas of these last three sewers the main weight of animal life consisted of specimens of *Mytilus edulis*, *Cardium edule* and *Mya arenaria*, although the main fish food animal was a much smaller species, *Macoma baltica*.

The largest areas in which the bottom fauna was effected were around the mouths of the Kløvermarksvej sewer and the two sewers which open at Svanemøllebugten. At the first of these a dead area extended 100 metres on each side of the submerged outlet, parallel with the shore. It was, however, only about 100 metres across. Outside the dead zone was a much larger area of bottom, covered with fetid mud containing H_2S and inhabited mainly by *Scoloplos armiger* and *Nereis diversicolor*, with a few *Mytilus edulis* and *Macoma baltica*. The specimens of *Scoloplos* had the appearance of being very well fed. Places in the channel (Kongedybet) were characterised by a mass development of *Mytilus edulis* and all places except the dead zone showed a productivity equal to that of unpolluted areas.

At Svanemøllebugten the two sewers discharge into a body of water somewhat confined between harbour works. Probably as a consequence the zone in which no animals were found was large (300×600 m.) but, outside this, there was no area of fetid mud with the well-fed polychaetes characteristic of the fetid zone at the Kløvermarksvej outfall.

II. The weather during the investigations was calm, and temperatures ranged about a mean of 8 to 9° C. The speed of the currents was below the average values for the Sound.

The surface waters of Copenhagen Sound have usually a salinity of about 8.0 g. per 1,000 g. and drift in a northerly direction. The bottom waters move southwards and have a much higher salinity of up to 25 g. per 1,000 g. The discontinuity layer was found, in May, to be at a depth of 8 to 10 metres.

No signs of pollution were discovered at the Sundby District III, Tuborg Harbour, Strandmøllen and Skodsborg outfalls, whilst at Hellerup, Hvidøre and Charlottenlund Fort a deoxygenation of the waters of down to 74 % of saturation was found.

Near the larger sewers of Kløvermarksvej and Svanemøllebugten,

water with a concentration of dissolved oxygen of less than 70 % of saturation was found.

The Kløvermarksvej sewer has a flow of 117,000 m.³ per 24 hours, and fouling of the water was discernible. At a distance of 50 metres the streak of polluted water was 50 metres wide and, from determinations of the salinity of the water in this zone and in unpolluted water, the dillution was calculated to be from 1 in 33 to 1 in 14. The different values were obtained by assuming in the first case that only surface waters of low salinity were involved in the dilution, and in the second case that the deeper waters were also involved. Salinity determinations in September gave an estimated dilution of 1 in 24. Assuming the latter dilution to be correct the current speed calculated from the width of the polluted zone and the flow of the sewer was estimated to be about 0.2 knots. This is less than the average speed of the currents in the Sound so that greater dilutions than 1 in 24 will be more usual.

The salinity determinations at the Svanemøllebugten outfalls where the flow is 12,600 m.³ per 24 hours, gave a calculated dilution of the sewage of 1 in 20. The confinement of the water by the harbour walls is thought to produce this small dilution and calm weather probably accentuates the adverse conditions.

Estimations of dissolved oxygen at Svanemøllebugten gave values down to 64 % of saturation. Near the Kløvermarksvej outfall the surface waters were found to possess a dissolved oxygen concentration of 67 % of saturation, although a few metres away a saturation of 82 % was recorded.

The dissolved oxygen depletion of the waters near the sewer outfalls is not due entirely to the mere absence of dissolved oxygen from the sewage since the dilution, calculated from salinity determinations, is too great to account for the observed fall in dissolved oxygen concentration.

In Kongedybet the water below the discontinuity layer was found to contain less dissolved oxygen than that above it. A comparison with the Hollænderdybet showed that similar conditions prevailed there, and since Hollænderdybet is unpolluted the low oxygen content of the bottom waters in Kongedybet is assumed to be due to stagnant conditions rather than to the effect of mud deposited from the Kløvermarksvej sewer.

R. B.

E. S. Russell. Fishery Research; its contribution to Ecology. Journal of Ecology. Vol. XX, No. 1, Cambridge, 1932.

This useful review of somewhat more than 20 pages, intended in the first place for the enlightenment of those whose scientific work lies outside this special field of ecology, begins with a short résumé of mainly scientific marine research of the last century, and, subsequently, of the founding of the International Council in 1902. Gradually the scope of the Council's work became centred upon special fishery problems, together with side-line researches such as the study of bottom fauna, plankton and hydrography. Careful commercial and biological statistics are of course the main basis of all this vast amount of work.

The author deals chiefly with investigations carried on in Great Britain. After discussion of the vast field of research to be covered by various methods, he proceeds to a »census of fish populations and its aims«, connected with the rate of mortality in fishes (judged by recaptured marked fish, change in the landings per unit time, the effect of thinning of the stock on growth, and so on).

An interesting chapter is devoted to »fluctuations and predictions« with

relation to cod, haddock and herring. With regard to the causes of fluctuation in the abundance of year-classes, interesting facts are mentioned about the evalution of available food, and in this respect a single patch of gregarious molluscs (*Spisula subtruncata*) on the Dogger Bank, estimated to reach the astounding figure of 4.5 billion individuals, is worth noting.

Hydrographical and biocoenotic factors form the subject of another chapter, dealing with the distribution and migrations of fish. The influence of plankton, especially with regard to the shoaling of herring, is also noted, and the well-known Plankton Recorder,designed by Hardy, promises to be of great use in the near future.

More strictly scientific researches on the biology of plankton organisms, Petersen's fundamental investigations on the ecology of Danish waters, in which *Zostera* plays such a great rôle in the lives of bottom animals that feed on fine detritus, — all this forms the subject of the last chapter.

In perusing this concise but most informatory article the reader, though awake to the vast problems of the ecology of the sea, will be grateful for being convinced that the right track to the solution, as illustrated by the irrefutably practical results already gained, has been very ably sketched by one who is entitled to do so, and will recall to mind the well-known German phrase about dealing with intricate problems in a concise form. The value of the article is enhanced by a full list of literature references. It is perhaps a pity that the author has confined himself mainly to British work, so that for this reason Le Danois' theory of annual transgressions of Atlantic water and its influence on the migrations of hake and white tunny, and Bückmann's description of abnormal temperature effects on plaice brood (though the latter may have been still unknown to the author at the time of writing) have been passed over.

J. J. T.

H. A. Harris. Lines of arrested growth in the long bones in childhood: The correlation of histological and radiographic appearances in clinical and experimental conditions. Brit. Journ. Radiology, Vol. IV, N.S., Nos. 47 and 48, London, 1931.

Dr. Harris produces radiographic and histological evidence to show that lines of dense ossification (»lines of arrested growth«) may occur in the long bones of human subjects as the result of diseases other than rickets, which has long been known to produce a similar effect. Such lines are not necessarily the aftermath of the latter disease alone, as has often been assumed, but are produced by a great variety of diseases and complaints, from severe colds to diabetes, which disturb the normal growth of the epiphysial cartilage. Starvation and poisoning are also effective in producing such a disturbance in growth, which is distinguished by a shrinkage of the proliferating cartilage cells in the epiphyses of growing bones and by the deposition of exceptionally thick calcified trabeculae transversely to the long axis of the bone.

Such metabolic disturbances produce the lines of arrested growth most readily in the young, whether *in utero* or adolescent, but particularly just after birth when the body-weight falls rapidly. Harris has observed these lines in a wild lamb (Moufflon) kept in captivity and has produced them experimentally in dogs and rats. He gives fifteen cases of children showing such lines and four cases of the persistence of the lines into adult life, even to the age of eighty-six. Clinical histories of a more or less complete nature are given in each case and an attempt is made to correlate the known serious

illnesses of the patient with the lines of arrest shown in the radiographs of their bones. Some of the evidence, especially in the case of remote illnesses, will perhaps strike a non-medical scientist as a trifle uncritical.

Since the long bones grow in length at their ends alone, the lines caused by early illnesses are found further and further up the shaft and persist into adult life to a degree depending on the individual and also upon the extent to which the bone is used and its tissues remodelled.

Dr. Harris compares these lines of arrested growth with the winter rings on the scales of carp and salmon and the annual rings in trees. He points out that these structures are produced by a seasonal variation in the metabolic activities to which man is not subject. In man the lines result from casual metabolic disturbance but they closely resemble the line of cessation of growth laid down at the time of epiphysial union (18—20 yrs.), and they may perhaps represent an incipient and transitory senility of the skeleton.

The paper suffers from diffuseness owing, perhaps, to its appearance in two parts, and it is liberally embellished with impressive classico-medical terms for which there are often more familiar synonyms (e. g. exanthemata = epidemics: pyrexia = fever: nociceptive = harmful: subjective symptomatology = (?) mental distress!).

J. A. R.

Current Bibliography.

Prepared by the Editor with the assistance of Miss Thursby-Pelham.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in the North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

The classification of entries follows in a general way that adopted in Dr. Allen's Selected Bibliography published in Vol. I, Nos. 1 and 2 of the Journal, and since reprinted (Price, 1 Kr.).

Subscribers and those on the distribution list will receive regularly upon application to the Administrative Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

Physical and Biological Conditions in the Sea.

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Table of Contents.

		Page
1.	Obituary Notice:— **James Johnstone** (1870–1932) by **R. G. Daniel**	3
2.	**H. J. Buchanan-Wollaston.** Some Modern Statistical Methods: their Application to the Solution of Herring Race Problems. With a Foreword by **R. A. Fisher**	7
3.	**Willy Bein, Heinz-Günther Hirsekorn** und **Lotte Möller.** Neue Konstantenbestimmungen des Meerwassers	48
4.	**G. E. R. Deacon.** An Examination of "Eau de Mer normale P 13, 28-VI-1928". With an Appendix by **D. J. Matthews**	59
5.	**H. C. Hamaker.** Results obtained with a Thermograph for Surface Temperatures during the "Snellius" Expedition	64
6.	**Helge Thomsen.** The Circulation in the Depths of the Indian Ocean	73
7.	**A. Buschkiel.** Experimentelle Beeinflussung von Schuppenbildern	80
8.	**C. V. Otterstrøm.** Reife Lachse *(Salmo salar)* in Teichen	83
9.	**Alf Dannevig** and **Erling Sivertsen.** On the Influence of Various Physical Factors on Cod Larvae; Experiments at the Flødevig Sea-Fish Hatchery	90
10.	Reviews	100
11.	Current Bibliography prepared by the Editor with the assistance of Miss **Thursby-Pelham**	126

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